SMITH

Handbook for Resident Engineers
On Railway Construction

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HANDBOOK FOR RESIDENT ENGINEERS ON RAILWAY CONSTRUCTION

BY

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I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

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FOR

PROFESSIONAL DEGREE IN CIVIL ENGINEERING

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A HANDBOOK FOR RESIDENT ENGINEERS ON RAILWAY CONSTRUCTION

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CHAPTER I

INTRODUCTION

SCOPE AND PURPOSE.- There are scores of handbooks containing convenient and useful tables, formulas and other data for practicing engineers but there appears to be none written to cover the field for the resident engineer on railway construction work, excepting the Manual for Resident Engineers by Moliter and Beard, and the private instructions issued sometimes in book or pamphlet form by the chief engineers of some of the railways for the use of their own employees. The writer believes, therefore, that there is room for, if not a call for, a handbook for resident engineers on railway construction.

The resident engineer holds a position which demands clsoe attention to business and the performance or supervision of numberless details of work of a great many varieties. His responsibilities are considerable, and, if conscientious, he is more than likely to find the days as fleeting and the nights as sleepless as does the general superintendent. The young engineer naturally feels the lack of time more than the veteran does, and, until he learns the short cuts and easier roads from experience, his work is more or less of a grind and never as effective as he desires it to be. It is the idea of making the residency work more effective, and the economizing of time, that prompted the writer to offer the suggestions and helps that are to be found in this manual. Engineers long in the service have most of this information as a part of their

second nature. The tables and formulas, however, have been so chosen and arranged that it is hoped they may prove useful to all construction engineers. It is often difficult, or at least awkward and inconvenient to carry a small sized library of engineering books upon a residency or into a camp and many engineers would often have welcomed a small edition of useful everyday information as a substitute. The writer recalls how keenly he felt the desire for something that would give the practical knowledge he wanted and when he wanted it, almost to the point of envying a sub-contractor his non-college, but practical education. Even the old engineer who at first shrugs his shoulders skeptically at this may see the point of the emphasis if he will reflect upon his own experience on his first residency.

It is not the purpose of the author to give many details of surveying methods, but to suggest some practical applications to railroad construction. The work presupposes a good working knowledge of surveying instruments.

No attempt is made to cover in detail the field outlined by this handbook but only to call attention to, and perhaps emphasize, those points which the writer feels should be emphasized. The usual contract and specifications generally cover the requirements of the work to which the resident engineer must give his attention but they are frequently technical and couched in legal terms and not always easily interpreted by one unfamiliar with them, and therefore cannot always be considered a reliable guide. The writer does not presume to elucidate specifications in this little volume but believes that almost any resident engineer qualified for his position who has a good set of his company's specifications and the

suggestions offered in the following pages should be able to perform residency work quite acceptably.

DEFINITION.- The title Resident Engineer as here used applies to the engineer in immediate charge of the work. He seldom will have more than a ten or fifteen mile section under his supervision. A few roads give this title to the engineer in charge of a large division of road, often from fifty to several hundred miles in length, and give the title of Assistant Engineer to the man in immediate charge of a small section. Frequently we find the following organization of the Construction department, the titles being given according to rank: Chief Engineer, Principal Assistant Engineer, Division Engineer, Assistant Engineer, Resident Engineer. On some roads the Resident Engineer reports direct to the Chief Engineer or Supt. of Construction.

It will be more convenient for the purpose of the author to refer to the Chief Engineer as the immediate superior of the Resident Engineer, and whenever superior authority is mentioned in any connection it should be understood by the reader as meaning the Chief Engineer, or his Office.

CHAPTER II

ASSUMING CHARGE OF THE RESIDENCY

GENERAL.- The resident engineer on railroad construction will generally have charge of from three to four miles on terminal, yard, tunnel, or bridge work, to perhaps fifteen or even twenty miles on light or easy construction. If the section is short he and his party will walk to and from work, but if long, the company provides a team and wagon for their conveyance.

Whatever be the magnitude of his work he should feel the satisfaction that comes from immediate supervision, or doing work first hand, and it may not be inappropriate to say that he should take such an interest in his work, and such a view of it, that he can feel a just sense of pride in its successful execution. Even though he receives instructions from his superiors in matters of a general nature, his work is never stereotyped or routine. His good judgment and common sense are ever given wide latitude and no little exercise in carrying out such instructions properly and to the best advantage.

He is usually well paid, but as in all other positions of trust and responsibility, if he does his work conscientiously and well, he earns all he gets. A young engineer is often inclined to ponder over this perhaps unduly, but after a few years the chances are that he will point back with much satisfaction to that first period of real responsibility and real hard work as his real professional beginning, and scarce give a thought to the salary he receiv-

ed. A usual salary for the resident engineer is $110 to $125 per month.

ORGANIZATION OF THE WORK.- Work upon a residency often times starts off with a rush but the engineer should take time to do considerable thinking about the lines and plans along which he should order his work. This is important, though it is sometimes made a matter secondary to the setting of stakes. Preparation for systematic work as far as possible is of greatest importance.

Perhaps the first step is the organization of the work of the party of the resident engineer. The most usual party consists of an assistant resident engineer, sometimes called transitman or instrument man, a rodman, a chainman or tapeman, and an axeman or stakeman. Instead of a rodman and a chainman there may be two rodmen of similar duties, responsibilities, and salaries,-often the better organization.

The assistant engineer will handle the transit and level, keep field notes, take the initiative in reducing notes, making calculations and getting up estimates and will take instructions directly from the resident engineer. The rodmen will handle the tapes, rods, etc., as directed in the field, assist in making calculations in the office, and take proper care of the instruments. The axeman or stakeman, who may also be the teamster, will make and drive stakes, see that stakes are always plentiful and supplied where needed along the line, and keep the camp or premises in order. Proper division of the labor, impressing upon each member of the party his exact duties as nearly as possible and the importance and responsibility of his position, will go a great way toward promoting rapid, easy, and frictionless execution of the work.

With tactful treatment an axeman may be made to take as much interest and pride in his small field of duty as the resident engineer does in his larger field. The interest that a resident engineer takes in the work of his subordinates is most often a measure of their own interest. There is no disputing the fact that an axeman who chooses stakes as a timber cruiser chooses No.1 ties, cuts them exactly to size, sharpens them to precision, piles them neatly and in the proper place, and finally drives them with hair splitting exactness, will prove to be one of the best time economizers in the whole organization. Although the organization of a party of only four or five men may seem a small thing its importance may be underestimated. Perfect harmony in a party that must live and work together for several months, or perhaps a couple of years, pays a good interest on the investment of time and patience spent in organizing. When a resident engineer is given only two rodmen and must do the instrument work himself, as is sometimes the case, it is all the more important that these assistants be trained to their special duties so that he can trust to their efficiency and distribute his own time properly.

EARLY BEGINNING.- Work should begin as soon as the party arrives upon the residency. A few days of loafing at the start may result in a congestion of work later. The contractors may arrive earlier than expected and perhaps before the line is properly checked. If stakes are given the contractor upon an unchecked line which is found to be in error, no end of complications in engineering work, and disgruntlements of contractors, may result.

Naturally the best results will be obtained if the men are kept busy at something even when work along the line is slack.

The axeman may replenish his stake pile, clean up camp and put it in order, run errands, grind his axe, and do other rainy day jobs; the rodmen may mend tapes, repaint rods, get force reports, copy notes from field books into office record books, check calculations etc.; the assistant engineer may check calculations, make maps, plans, and profiles, and devise means for facilitating the work when the rush season arrives.

Something can always be found to employ the party, and instilling the men with business ideas will work to better advantage than permitting them to entertain the old illusion that between monthly estimates all they have to do is to sit on the bank of a cut and watch the mules. It should also be remembered that the contract between the railway company and the contractor limits the time of completion of the construction work, and the resident engineer should see that no excuse for delay can be justly laid at his door.

ADJOINING RESIDENCIES.- An early understanding between the resident engineers upon adjoining residencies is essential. Early acquaintance, frequent consultation and exchange of ideas concerning the work are always beneficial. The alinement of the road should be checked by both resident engineers, overlapping the survey far enough so that no "kinks" are introduced between the residencies. The same applies to the check levels. The engineers should satisfy themselves that there is no difference in datum sufficient to produce an objectionable break in the grade line. Sub-contractors may have work common to two residencies which will be facilitated by the cooperation of the engineers. Land owned by one man may cover parts of two residencies and better adjustments of the loc-

ation of road crossings, culverts, and drainage ditches, may be made if the engineers talk these matters over together.

STUDY OF CONTRACT AND SPECIFICATIONS.- The resident engineer should secure a copy of the contract between thr railway company and the contractor, also a copy of the specifications, and devote sufficient time to their study to at least become familiar with them. They will serve as his Primer and probably his Commencement Oration, and put him in touch with his duties better than anything else; but they must be considered with some discretion generally, and with a whole lot of common sense always, to make them fulfil their purpose. Unfortunately for the inexperienced engineer, the literal interpretation of a clause does not always convey the true intent of the provision. In such doubtful specifications it is best to learn if possible the intent before trying to enforce it. A man of practical experience will soon lose his respect for the authority of an engineer who attempts to hold to the literal interpretation of an ambiguous clause in a contract and tries to enforce it. No set of contracts and specifications is perfect and few approach perfection and it is therefore necessary that ~~that~~ they be studied carefully. In most instances perhaps the imperfections are introduced through ambiguous or poor use of language. Sometimes, however, clauses apparently unreasonable are inserted and perhaps were never intended to be executed, but used simply to spur on some contractor who is inclined to slight his work. A common clause states that the work must be completed within a specified time or the company shall have the right to add the necessary force to complete it at the contractor's expense, or shall retain a certain percentage or bonus for each month that elapses after the time

specified for completion. This looks formidable, and sometimes is dangerous, to the sub-contractor against whom it is enforced by the general contractor; but it is not often that a railway company enforces such a provision against the general contractor if he does everything reasonable to fulfil his contract.

There are too many unforeseen circumstances which even the most experienced man cannot take into account when he bids upon a piece of work, and it is unjust to take advantage of him simply because there is an opportunity through an unreasonable clause or one intended to apply to the negligent or viciously inclined contractor.

There is an infinite number of circumstances which may arise during the progress of the work to influence its execution, and consequent cost, and it is therefore manifestly impossible to frame a set of specifications that will cover all contingencies. The engineer must not expect to find in them a cure for all ills, but he may with good judgment find some most helpful methods of treatment of the various cases that may arise. A good set of specifications should be looked upon as the best results of years of engineering experience. It is not bad practise for a resident engineer to memorize such specifications, to some extent at least, and perhaps quote them as occasion requires. A thorough knowledge of them may prove an asset to his standing as an engineer in the sight of them over whom he exercises supervision.

A familiarity with current prices of materials, and costs of methods and labor, will often prove of considerable value in connection with the study of specifications. It is suggested that the contract sheets of the engineering periodicals be consulted frequently.

Discussions that would fill volumes have been written upon the pros and cons of certain clauses in contracts and specifications,- upon their merits and defects. There are poorly written ones and well written ones, but after all the engineer will find that it is a matter of good judgment and common sense as to how they may be interpreted and applied in the field where the work is being done.

DEALINGS WITH CONTRACTORS.- All dealings with the contractor in connection with the work should be businesslike and formal. Loose methods and loose manners, discourtesy, and familiarity, all tend to lessen the influence and belittle the position of a resident engineer. Constant contact and close acquaintance with the men on the work often has a tendency to develop these traits perhaps even more in the other members of the party than in the engineer himself. The engineer should place himself under obligations as little as possible, for the more independent he is of such obligations the easier it will be to deal fairly and make up estimates without bias. This point is sometimes emphasized by the railway company in forbidding their resident engineers and parties to take meals with the contractors, at least, without paying for them. This ruling was probably made because some engineers have made it a practise of "just passing along" the contractor's kitchen tent always about meal time, and they could never refuse or resist the urgent invitation to drop in and have a "smack" . The invitation and square meal may have been designed to so intoxicate the engineer that at the end of the month he could estimate 50 yards of earth in a 25 yard pit; but the engineer if qualified for his position should always have sense enough to know when to accept and when to refuse obligations, and the writer sees little use for making any rest-

rictions upon him as far as his meals are concerned. In the supervisory work that an engineer is required to do, it frequently happens that he is called upon to demand that certain things be done; that a cut be dressed as the work proceeds, or that ditching be done in advance of opening up the work, etc. Unless he is watchful he may find himself cultivating the habit of giving the contractor commands where he has only a right to suggest or instruct. He has little power to enforce a command - not as much as he often thinks is vested in his office. The wiser thing to do if a request has been made to carry out a specification and the request has been unheeded, is to report the neglect to the chief engineer or general contractor. Sometimes appealing the case of a sub-contractor to the general contractor or his line representative will accomplish the desired result without troubling the chief engineer. It is well never to carry petty difficulties to the chief if they can be settled properly by the resident engineer himself. The practise of parading up and down the line giving orders as if he were a general in charge of an army, defeats its purpose and is to be condemned for its moral effect if for no other.

The resident engineer should satisfy himself as to how far he can properly go in issuing instructions or orders to the contractors. A contractor may be working under a clause in the contract which says that he shall be responsible for all damages or injuries to employees. He begins a cofferdam for a pier, the engineer comes along and orders him to use his methods in constructing it. It fails, injuring several men. The placing of responsibility then becomes a question which the court will probably decide, and, in spite of the clause in the specification, the fact that the eng-

ineer ordered the methods of construction will in all likelihood exhonerate the contractor. It has been so decided in one case.

The above clause may also have appended the provision that the work shall be done as directed by the engineer, that is, that the engineer shall specify the methods to be pursued. The engineer does his duty, the accident happens, and it is perhaps more clear than in the former case that the engineer is responsible. The point for the resident engineer to keep in mind is that he is not the "Engineer" named in the contract unless the chief engineer or some one else high in authority confers that title and its duties and responsibilities upon him. It is best to proceed slowly in issuing directions to contractors. If there is any question as to the authority of the resident engineer in issuing instructions, the chief engineer should be asked to settle the matter. Instructions or other information given to contractors should always be in writing if practicable, and the engineer should retain a copy or make a minute of such communications in his diary.

CHAPTER III

GENERAL DUTIES OF A RESIDENT ENGINEER

CONSIDERATION OF THE COMPANY'S INTERESTS.- The first duty of a resident engineer is to carry out the will of the company through the instructions of his superiors. He may have opinions of his own as to how the work should be done but they may not be such as will work out to the best interests of the railway company, and his services will be less prejudicial to these interests if he assumes charge in the attitude of a servant rather than a dictator. Promptness and accuracy in obtaining information required by the chief, and definiteness and conciseness in correspondence are desired. Telephone and telegraph if available should be used where important information is to be transmitted with all possible speed. Long messages are expensive if sent by foreign lines, and the time required for delivery should be considered carefully. Frequently a letter makes almost as good time as a telephone or telegraph message and is much more satisfactory.

The resident engineer may serve the company in the capacity of a diplomat by obtaining the good will of the inhabitants along the line of the railway and putting the company in a favorable light before them. He should accord them courteous treatment and receive their many petty and often rediculous questions kindly and with a goodly supply of patience. They usually mean well and although their questions may seem prying, it is most often their attempt to be cordial and interested in the engineer's work that makes them inquisitive. If a question is asked, the answer to

which involves a company secret, the questioner should be politely told that the engineer has no authority to give out such information. Frank and honest answers are far better than fabrications, for the resident engineer will often remain on the work several months or a year and may be held to account for his behavior before he leaves the work. The railroad will exist and depend upon the locality for its support long after the resident engineer has gone but may have to reap the good or bad effects of his influence. The resident engineer is a busy man, but policy may make it a paying proposition to let Jonas "take a look through that air camery" upon request, even at the expense of releveling, or resetting upon the back sight.

It is not intended to give the impression that the engineer should become familiar with the people to the point of excessive indulgence in their questions and whims. Sometimes he may be bored and perhaps hampered in his work by their insistant talking and "hanging around"; but ignoring such parasites and attending closely to business will give them little to feed upon and they will soon leave him for richer fields.

As has already been intimated, the upright and business-like dealings with the contractor are a part of the duties of the resident engineer. He should keep in mind the fact that the contractor is on the job to make money and that he deserves all that is fair and honorable, and it is as much his duty to see that the contractor is given everything he earns as it is to see that he is given anything he earns; and it is never his duty to discourage the contractor from making all that he can fairly. Sometimes the engineer is forbidden to give out any information to contractors without

~~without~~ the approval of his superiors, or if information is requested he is instructed to refer the matter to the chief engineer for the answer. This, in the writer's mind, may sometimes work an injustice. The contractor has a right to know about what work he is doing and how much he is given credit for and paid for, and there is little reason why he should not see the engineer's record if he so desires. If they are kept in a business-like way, as they should be, no harm can result, and the fact that they are open to inspection is an encouragement to the contractor, not only in showimg him how his work stands, but in convincing him of a square deal. If the engineer's judgment cannot be trusted to give out information with discretion, then the chances are that he is not the man for the position.

The resident engineer is responsible to the company for all the equipment that he receives with which to do his work. The condition and appearance of the instruments or tools are sometimes accepted by the chief engineer as the index of the character of the man who uses them. A dented sunshade or cracked tripod leg may be evidences of carelessness. The instrument man and the rodman should know how to take good care of the instruments, and if they do not, they should be taught how, and impressed with the cost of the equipment that is entrusted to their care. It is often stipulated that any losses due to careless or thoughtless treatment shall be made good by the resident engineer.

The transit and level are delicate mechanisms and must be handled intelligently to give accurate results in the particular work for which they were intended. When shipped they should be packed well with excelsior, cloth, or paper, so that there will be no

"play" or jarring about in the box; as anadditional precaution this box should always be packed in another box. If carried in a wagon, it is always safest to support the instruments with the hand instead of allowing them to receive the jolts of the wagon. The rodman should hold the level rod also when riding in a wagon. Care should be exercised in taking an instrument out of its box, lifting it by the plates or leveling base and not by the telescope or standards. It should be protected from the rain and snow or wiped dry as soon as possible after being exposed to dampness, and never left unprotected in a pasture, street, or where teams, blasting, or meddlers are likely to harm it. Rodmen should be warned against jumping ditches with a transit ar level on the shoulder, allowing the needle to swing when carrying, using the instruments for coat racks, the level rod and transit poles for vaulting poles or snake killers, the axe for sharpening stakes upon the ground or for hacking every object that is unfortunate enough to be located in his path. Caution should be used in carrying a transit or level through timber country, especially where there are low hanging branches to catch upon the instrument head. Usually it is best to clamp the level slightly in such a position that when held upon the shoulder the telescope is in the same plane with the body of the carrier, and is thus protected at the front, and from catching limbs at the side. The telescope of the transit should be clamped very slightly so that a jar will not cause undue strain upon the clamping screws. Instruments should be kept in the box while in camp.

The steel tape should also be given attention. Because it is a simple piece of mechanism, it is often neglected, when it really deserves as much care as any of the other surveying instruments.

When wet it should be wiped dry. It should never be left in the camp wet and muddy as it rusts easily and the graduations become difficult to read. When rusted it may be cleaned with fine sand, and oiled with vaseline or watch oil.

In spite of the care exercised in handling instruments, they will get out of adjustment. The adjustments should be checked frequently, and where a party is stationed for some time at one place it will pay to arrange some stakes and fix points for transit adjustment; also to determine the exact difference of elevation of these points for level adjustment by the peg method. Three stakes may be set about 250 or 300 feet apart on the same straight line, the points being fixed exactly in line by foresighting from one of the end stakes. The middle one may always be used as the set up point and the adjustment checked by sighting upon the end stakes.

Aside from his other duties, the resident engineer is expected to give attention to the possible improvement of the engineering features of the line. Being familiar with all the physical conditions of the location and construction, he is in a position to note advantages that may be developed by changes in alignment, grades, vertical curves, water ways, etc., and to suggest or submit such changes to his superiors for their consideration. He should never take it upon himself to make any changes in the plans unless instructed to do so by the proper authority. His proposed changes may not appeal to others, however reasonable they may seem to himself, and he should go no farther than to give reasons and arguments for their adoption. He should not allow himself to become so narrow as to neglect to suggest advantageous changes simply because the construction work has begun and the changes would involve more

work on his part. He may be burdened with other work but he owes it to the company and to himself to give some time to the consideration of improvements, and if necessary he should make a requisition for additional helpers that the best interests of the company may be served. Finally, his chief duty is to see that all construction work is executed properly and according to contract. This is one of the most important reasons for his being styled a "resident engineer". The minutest details must receive his attention. In a measure the larger problems are handled by his superiors, but the details are none the less important, and, unless he sees that the work is performed as staked, no negotiations of problems in the chief engineer's office would make the road bed safe and perfect in condition, as desired. The promoter conceives the project of a railway; the directors give it an opportunity to develop; the president executes the policies of development; the chief engineer is assigned by him to act upon the engineering features and make the plans for the practical construction; while the resident engineer sees that these plans are carried out as designed. Therefore, although low down in the succession of offices, his duties are the key to the satisfactory consumation of the project. Unless these duties are fully comprehended and properly performed he is not giving the company the results contemplated by his employment.

CHECKING THE SURVEYS.- The engineering work to be attacked first upon entering a residency is the checking up of all the work as left by the Locating Engineers. The resident engineer must be sure that the skeleton work - the surveying - is right, before he goes ahead. As in all engineering work, "check" should be his watchword.

First, the transit work should be checked, verifying or correcting the alinement notes. Next, the levels should be run and all bench marks checked. It frequently happens that the contractors are ready to begin work before the resident engineer has had sufficient time to check both alinement and elevations over the whole line. This is unfortunate, but at least that part where the construction is to begin must be carefully checked. A good rule is never to give construction stakes before the line has been verified. This, however, is rebutted by the rule which says "Never keep a contractor waiting for construction stakes". The interpretation of this last rule is, that to keep the contractor waiting after he is ready to begin, as per contract, makes the company liable for damages, or at least gives the contractor ground for registering excuse for delay at some future time when the company wishes to urge him along in his work. Difficulties of this nature can, in nearly every case, be avoided by showing the contractor that checking the line first will serve mutual interests.

Waterways, bridge openings as determined by area of waterways, high water marks, etc., should be checked as early as possible, but this work may usually be done to suit the convenience of the engineer. Mention will be made later of the work of checking the notes of the Locating engineer, under "Preliminary Work."

STAKING THE WORK.- It is the duty of the engineer to stake out all work to be done by the contractor. This means that practically every kind of work that is to be performed should have its scope and limits determined by engineer's stakes properly marked. It requires many stakes and much labor and the engineer is likely to slight this more than he should, but ample and careful staking

always pays in the end. When the contractor is justifying some gross blunder he has made by trying to convince the engineer that there were no stakes set, or that they were set somewhere else than where they ought to have been, the unearthing of an inoffensive stake with an unmistakable engineer's mark upon it will work wonders in relieving the situation so far as the engineer is concerned. If the resident engineer has the reputation for accurately and completely staking all work, he takes temptation away from the man who is inclined toward crooked work, and in addition, has the testimony of the stakes to justify all his calculations and estimates.

It is the duty of the resident engineer to furnish stakes, lines, elevations, plans, etc. whenever necessary.

MEASURING THE WORK.- As the residency work proceeds he must make the necessary measurements for determining the amount of work done. The measuring up of the work will be greatly facilitated by having the stakes carefully and accurately marked and set, a feature which is not always foreseen or realized until the measuring up begins. The time for the work is usually limited, perhaps to the last two or three days of the month, in case of monthly estimates, and there is little time to spare for referencing in and rerunning a line and resetting the construction stakes, work which is sometimes necessary to obtain reliable measurements. The estimates are required to be in the chief's office by the first of the month or as soon thereafter as possible. The emphasis is always on "the first of the month," but they had better be a day late and in such ~~a~~ shape that the engineer will feel no compunctions in certifying to them as correct, rather than on time, but inaccurate and unreliable.

All work, without exception, shown upon an estimate sheet should be based upon, or accounted for, by field measurements. There is

seldom a borrow pit so obscure, or an excavation so irregular, or a clearing so indefinite that some approximate measurements may not be taken; and such instrumental measurements, though crude or approximate, are likely to be far more accurate than guesses or "eye measurements". Besides, they are records which can be referred to later if questions arise. It is poor engineering to make a verbal agreement with a contractor to take so many cubic yards as an estimate, or to lump off a piece of work with no record as to how it is done. This may be permissable in extreme cases where the work is nearly complete and a final estimate is soon to be made, but it is not advisable even then. There is always a danger of over-estimating quantities if the work is lumped, and an over-estimate is a hopeless thing to straighten out after it goes on record in the chief engineer's office. On the contrary , if the engineer makes his estimate too small, dissatisfaction follows and he has nothing but a guess to substantiate his results and defend his position.

The measuring up of the work by the engineer is a part of the contract and any compromise with a contractor to the contrary is a violation of the spirit and intent of the agreement and should not be indulged in by the resident engineer.

CALCULATING THE QUANTITIES.- The calculation of the amount of work performed, together with the making up of estimates from time to time as required, is one of the most important duties of the engineer. The calculations must be accurate and to this end should be checked and rechecked. There is a multitude of detail results to put upon an estimate sheet, each of which may be reached by several successive processes of computation. This fact is not always considered by the office force to whom the estimates are sent, and if

a single error is made in calculation, or even in copying, the author of it is likely to be charged with a "mistake" and possibly styled a careless engineer. As it is impossible for him to make all the calculations himself, he must see that his instrumentman and rodman are well trained and impressed with the responsibility which they should share. If possible, he should be in the office to assist and direct all of this work, but if duties out upon the line are urgent he may have to turn practically all of the work over to his assistants. Order and systematic methods of calculations are then of great value, for in the rush of his duties it should be possible for him to hastily examine their work and feel safe in certifying that it is correct.

KEEPING RECORDS.- The keeping of complete and accurate records is ~~the~~ most essential on residency work, and it is no small part of the resident engineer's work. As indicated above, all field estimates and measurements should be matters of record, and the calculations necessarily so. In addition to these there are many other things that transpire that should be kept on record, but which unfortunately are sometimes made only memory exercises. Instructions to contractors and even conversations bearing upon some questionable points at issue, information received from the inhabitants along the line, the exact dates of beginning and completing each piece of work, and all items that have important connection with the work even though not strictly engineering problems, are things that should be "inked in" either in the office records or in the pocket memorandum. The clerical force is of course limited and the resident engineer may feel that he has no time for such work, but a large amount of this work can be made a matter of habit. A daily-

ly memorandum does not require much additional time. Notes may be jotted down at lunch time, while waiting for trains, etc. and need not require a day off for posting. The fresher the information when posted, the more reliable. The writer has in mind one engineer whose practise it was to wait until Saturday night or Sunday, then call in all his party and require them to help bring back the memories of the week just passed so that his diary might be kept in compliance with the instructions from headquarters. This practise is not to be recommended. Records should not be discounted to this extent.

The old adage that "the engineer's foresight should be longer than his hind sight" still holds and nothing measures his foresightedness better than the keeping of good, comprehensive, and accurate records. Seemingly minor events, and careless assertions made by the engineer at the beginning of the work, often become exaggerated unless recorded and not infrequently develop into events of considerable consequence when the time for final settlement arrives. The records should be so complete and well kept that anyone may readily understand them. The value of this is appreciated especially when one engineer takes up the work of another. Poorly kept notes give rise to almost endless confusion at such a time. The engineer leaving may not have time to go over the work and records to explain them fully to the new man. Much time is lost, a sense of uncertainty always exists with the successor, and the reputation of the predecessor is looked upon rather doubtfully.

CHAPTER IV

EQUIPMENT AND SUPPLIES

Requisitions for the necessary equipment and supplies should be made as soon as it is known what will be required to conduct the work. They should be made regularly at the beginning of the month so that the chief engineer may know what his requisitions will be upon the storekeeper, or what stock he will have to keep on hand to supply the various residencies. It has a better moral effect and indicates a more businesslike policy to make out a complete list of supplies at one time, than to be continually asking for one or two articles at a time the whole month through. Requisitions are made upon the blank forms furnished by the chief engineer and are signed by the resident engineer.

It is not advised that the resident engineer be extravagant in his requests, but he should abandon the idea that scrimping is economy. Perhaps he is not always encouraged as much by his superiors in this respect as he should be. The health and comfort of the party demand good and sufficient food, ample bedding and as many other conveniences as are consistant with the length of time that they will be located in one place. Good instruments and tools and sufficient help, with the privilege of hiring an extra man during rush seasons, all conduce to the dispatch of the work. If the engineers feel that they are treated well and will be granted what they ask for within reasonable limits, they are bound to feel more interested and at home with the work. A few dollars invested

to amply equip a party will pay a most satisfactory dividend in the additional results obtained.

Below are given lists of supplies which will suggest most of the essentials to a complete equipment at the beginning of the work:

OFFICE EQUIPMENT.-

I		Desk equipment.
IO	yards	Duplex detail paper.
IO	"	Tracing cloth
IO	"	Profile paper. Plate A heavy.
IO	"	" " " " tissue.
IO	"	or 2 dozen sheets of cross-section paper, ruled in tenths.
I/2	dozen	Scratch pads.
2	pads	8 I/2" X II" letter paper.
I		Letter copy book.
I/2	dozen	Sheets carbon paper.
IOO		Small envelopes.
IOO		Large envelopes.
2	dozen	Extra large envelopes.
I/2	dozen	Blotters.
I	bottle	Writing fluid.
2	"	Black waterproof ink.
I	"	Red waterproof ink.
I	"	Blue " " .
I	"	Yellow " " .
I	dozen	Colored pencils or
I	"	Water colors. Conventional colors. (See Progress profile.)
2		Camel hair brushes.
6		2-H pencils
6		3-H "
6		5-H "
3		Ruby or emerald pencil erasers.
2		Rubber ink erasers.
2		Ink stands.
I	box	Assorted rubber bands.
I	dozen	#303 pens.
I	"	#404 pens.
2	"	Assorted pens, Old reliable, falcon, crow quills, mapping pens, etc.
3		Penholders, small grip.
3		Penholders, large grip.
I	box	Thumb tacks.
I	"	Paper fasteners or clips.
I	"	Paper tacks, assorted lengths.
I	paper	Banker's pins.
I	bottle	Office paste.
I	ball	Wrapping twine.
2		Transit books.
I		Level book.
3		Cross-section books.
2		Books for drainage areas, topography, etc.

2	Bridge books.
2	Masonry "
2	Material "
I	Cross-section plat book, or record book.
I	Receipt book for cash expenditures.
2 dozen	Expense account blanks.
2 "	Pay Roll "
2 "	Detail estimate sheets.
2 "	Total " "
I "	Requisition blanks.
I pad	Force report blanks.
2 dozen	Shipping tags.
	Annual or monthly inventory blanks.
	Weekly report of material received.
	Daily report of track laying.
I - 36"	Steel straight edge, or
I - 36"	T square.
I - 45°	5" triangle.
I - 45°	I2" Triangle.
I-60X30°	I2" triangle.
I	IO" celluloid or steel protractor.
I	Steel eraser.
I set	Good drafting instruments.

The resident engineer should procure the following from the chief engineer's office by requisition:

(1) A copy of all original notes and memoranda concerning his residency as obtained by the Location Survey party.

(2) A copy of the latest working profile showing grade lines adopted. The grade lines are frequently changed in the chief engineer's office for improvement and the resident engineer should be sure he has the latest revised copy before he lays out the work.

(3) Copies of the Right of Way maps to date. The properties along the line are not always settled for before construction begins and he will be greatly aided by knowing of the acquisitions of the company as soon as possible.

(4) Copies or blue prints of the following standard plans; roadbed sections, culverts, trestles, bridge and masonry plans for special structures, tunnel sections, station plans, yard plans and siding plans. These last mentioned plans are often late in reaching the

residency, since there are a great many factors ~~in~~ influencing the choice of sites for stations and sidings, in addition to the most advantageous physical location. The property is often difficult to acquire at a reasonable price if the owners are inclined to be stubborn or not friendly toward the railroad. It may be that actions by City Councils must be waited for. Traffic conditions and sources of revenue require study, and they cannot be well studied except through the light of information gained while construction work is in progress.

The plans, or at least some information concerning the possible location, should be obtained as soon as possible. If no information is available, the engineer, knowing the policy of the railway, may use his judgment or make an intelligent guess as to where the stations should be located. The stations are generally spaced at comparatively regular intervals, perhaps four to six miles apart, on summits rather ~~high~~ than in sags, near good water supplies, where switching or standing trains will not block streets and make crossings dangerous, where grading will not be excessive, and where drainage will be good. Should it be necessary to proceed without the plans, these considerations will assist in choosing the best distribution of the earthwork and prevent useless grading. The writer has in mind an instance where the main line was graded from borrow pits extending from berm to fence lines, thus using all the available material. Later it was decided to put in sidings and a station at this place, and embankment material had to be borrowed and hauled beyond the free-haul limit to fill up part of the original borrow pit. Rather poor economy, but possibly unavoidable.

(5) A copy of the contract and specifications.

(6) A good sized drafting board and supports 3' X 6'.

(7) A small drafting board about 24" X 30" is convenient.

FIELD EQUIPMENT.- The resident engineer will generally receive his field equipment from the chief engineer. Should it be left for him to choose the necessary instruments, the few general specifications indicated below may be helpful.

Transit.- Not less than a five inch horizontal circle, graduated in both directions from zero to 360° with slanting numerals, inclining in the direction toward which they increase. Two verniers reading to single minutes. A complete vertical arc not less than five inches in diameter and reading to minutes. Stadia wires. Level bubble under telescope with a sensitiveness of "I/IO inch of travel equals 20 seconds of arc", which makes the transit as reliable for leveling purposes as the engineer's level. Plate bubbles should have a sensitiveness of "I/IO inch equals 30 to 40 seconds of arc". Magnifying power from 20 to 25 diameters. Aperture of objective not less than I I/8 inches in diameter. The compass needle should be not less than four inches long. Provided with shifting center. Tripod with solid legs.

2 Transit poles. Hexagonal I I/4" X 3'.

IO Yards plumb bob cord and intersection string.

I Brass plumb bob.

I Box tacks.

I 3 I/2# axe (or 2 axes in timber country).

I Box blue crayon. (Dixon).

I Extra axe handle.

I Magnifying glass.

Level.- Sensitiveness not less than "I/IO" travel equals 20

seconds of arc". Magnifying power not less than 25. Erecting eye piece. No stadia wires.

I Level rod.- I3 foot extension self reading rod.

I Cross-section rod graduated to half tenths of feet. This is not considered essential to the equipment.

I Iron turning point.

I Hatchet, with extra handle.

I Hand level.

I I00' Steel tape I/4" wide, with numerals marked at every foot and the first foot graduated to tenths. Leather thongs for handles.

I 50' Steel tape in case, for use on bridge and masonry work.

I 6' Steel pocket tape graduated to inches on one side, tenths on the other.

I 50' Metallic tape in case.

2 Metallic tape fillers.

I Set chaining pins.

2 8 oz. iron plumb bobs.

I Steel tape repairing outfit.

I Sounding rod I/2" X I2'.

I Hand saw.

I Spade.

I Sledge.

I Broom.

2 Files, one flat, one triangular.

I Whetstone.

Stakes.- In timber country, the survey and construction stakes can usually be made on the residency, but when timber is scarce it will be necessary to make requisition for them. The sizes best ad-

apted will of course depend upon the nature of the country, whether prairie, mountainous, swampy, etc. A few general suggestions as to comparative sizes for different kinds of work are given.

Center line survey stakes for marking stations 3/4"X 1½" I/2"X I2".

" " " " " " transit points------------ I I/2" X I I/2" X 8" to I2".

Cross-section stakes-------------- 3/4" X I I/2" X I2" to I6".

Grade or finishing stakes--------- 3/4" X I I/2" X I0" to I6".

Track centers--------------I I/2" X I I/2" X I4" to I8",hard w.

Ballast stakes------------------- I I/2" X I I/2" X 24" to 30".

Right of Way stakes-------------- " " " " .

Fence line stakes---------------- 3/4" X I I/2" X I2".

CHAPTER V

RECORDS

The importance of keeping careful and complete records was emphasized in a preceding paragraph as one of the duties of a resident engineer.

Items for record should be entered without delay. It is good practise to make the entries habitually at the end of the days work and not to put them off until there is more time. Records are sufficiently important to demand a definite appointment of the engineer's time, and further, if attended to every day no important feature or item is likely to escape the memory.

The following notes will be found useful in suggesting some of the things that must be considered in keeping records on a residency.

For convenience, records will be treated under the two headings, Office Records, and Field Records. Under the former are placed those notes and items of which there should be permanent transscripts. These should not be removed from the office. Aside from letters, expense accounts, pay rolls, instructions, etc., most of the items are such as must be copied from the books which are used in the field. These office records should be inked. Under Field Records is included the data taken in the field in its original form and which need not be transferred to other books. When the book is full, it is filed in the office but may be taken out upon the line whenever needed.

OFFICE RECORDS.- Copies of all letters, and instructions given should be fept on file. Copy books containing one hundred pages or more may be obtained and a lose carbon paper used for impressing the copy of the letter upon the page. The pages should be numbered, and may be indexed, thus forming a compact and convenient letter file; or loose leaves may be used with carbon paper for making copies and the letters filed in the ordinary letter file box. On account of the variety of blank forms that can be used to advantage on a residency, and the ease of making copies, a typewriter often proves a good investment.

An extra copy of the profile of the line and an extra copy of each plan used is convenient and often necessary. It is bad practise to carry office plans and profiles into the field. They become crumpled, and shrunken, the lines and figures obscured, and not infrequently lost or destroyed. The engineer then finds himself waiting for a new plan or profile when he is sorely in need of one. Plans and profiles carefully drawn and posted, or constantly revised to date, will often make it possible to dispense with book records.

The following books are the most essential ones for office records. If the company does not furnish special books, the ordinary field book serves well for all records except those concerning earthwork. This is better placed in a very much larger book. The ruling of field books may be conveniently changed with red ink to suit the headings required, They are durable and comparatively cheap.

The letter copy book is of special form as has already been mentioned.

Inventory book. If inventories are required every month, a separate book may be necessary, but if required only every six months, space can probably be found in some other book.

A book containing a record of the monthly expense accounts and their distribution, pay rolls, pay checks, and time checks received and given out.

Receipt book of cash expenditures. An ordinary blank receipt book for use in taking receipts for cash paid out on company business to accompany the expense account when sent in at the end of the month.

A book of material received and handled, to include office and field equipment, construction material, track material, in fact everything for which the engineer must give a report.

A book for keeping record of all earthwork data,- cross-sections, measurements, calculations, and results for monthly and final estimates.

A book for recording bridge work data, measurements, calculations and results for estimates.

A book for record of force reports. Instead of a book for this purpose, a copy of the report as sent to the office each week may serve, but a book recording the daily report is better. The collecting of force report data is usually left to a rodman and he too frequently records it on a loose slip of paper, which, if it lasts till he arrives at the office, is of little use afterward. Force reports are often considered an extravagent waste of time by the residency party, and probably are when collected by counting men and teams through the transit telescope or asking some straggling laborer how big a force he saw working down the line!

FIELD RECORDS.- Records for field use consist of the following:

A field profile, or better, a field profile book. A profile book is conveniently carried in the pocket, notes can be easily written upon it and the record can be well preserved. If the company does not furnish one, it is not a bad investment for the engineer to purchase it for himself. A rolled profile is undesirable in the field. It is hard to manage in a wind and difficult to write upon.

Field books.

A transit book for alinement notes, reference points, etc.

A level book.

A book for taking data for drainage areas and topography.

A book for bridges, buildings, and culvert data, for use in staking out work.

A book for surveys of property plats, right of way plats, and station grounds.

A book for recording measurements for estimates.

A book for recording cross-sections, excavations, embankments, borrow pits, etc.

A book for use by the masonry inspector.

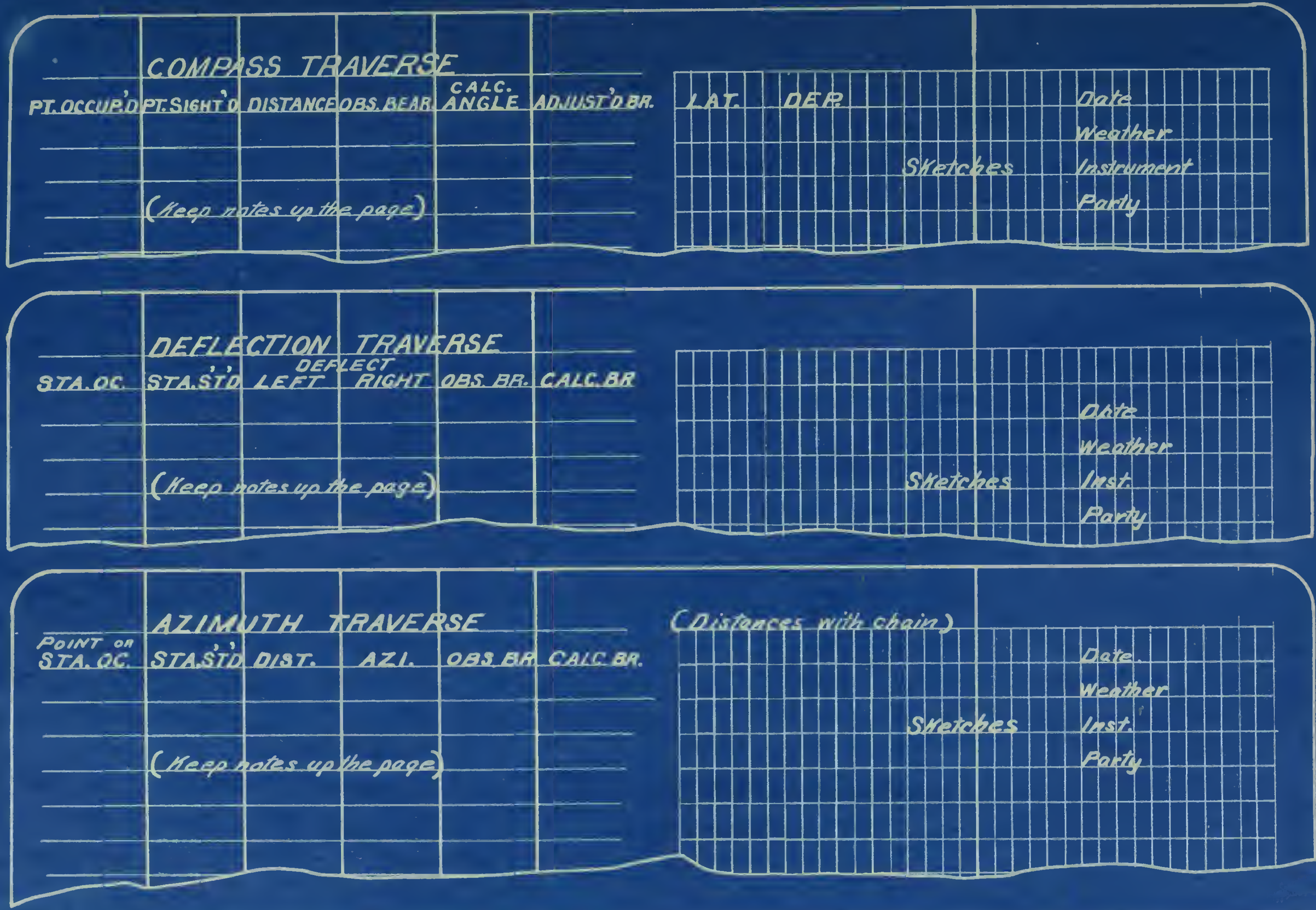
A book for use by the tie and timber inspector.

A book for recording material received, checked, and shipped, (including car loads).

A book for recording the daily force report.

A Diary or Pocket Memorandum.

FORMS FOR TRANSIT NOTES



g.e.s.

FORMS FOR TRANSIT NOTES

AZIMUTH TRAVERSE (Distances with Stadia)

STA. OC.	STA. S'D	AZI.	STADIA	DISTANCE	VER. ANGLE	VER. COMP.	H. I.	ELE.
		(Keep notes up the page)						

Sketches

Date
Weather
Instrument
Party

OBSERVATION FOR AZIMUTH OR LATITUDE

NUMBER OF OBS.	TELESCOPE	R.R. TIME	MEAN SOL. TIME	HOR. ANGLE	VER. ANGLE
	(Normal or Reversed)			(For Azi.)	(For Lat.)

Remarks, Sketches, Calculations, etc.

Date
Place
Inst.
Party

CURVE ALINEMENT NOTES

POINTS or STA.	DESCRIP. of POINTS	DEFL. ANGLES	TANGENT OBS. BR.	TANGENT CALC. BR.	CURVE FUNCTIONS
	(Keep notes up the page)				

("DEFLECTION TRAVERSE" form of notes may be used also for "CURVE ALINEMENT NOTES")

Sketches
Reference Points
etc.

Date
Weather
Inst.
Party

J.E.S.

FORMS FOR LEVEL NOTES

DIFFERENTIAL AND PROFILE LEVELING

STA.	B.S.	H.I.	F.S.	ELE.	BM.&T.P.	DESCRIPTION OF BMs, & REMARKS
						Date
						Weather
	(Keep notes down page)					Inst.
						Party

FIELD CROSS SECTION NOTES

STA.	TURN. PTS	GRADE	GR. ROD	ROD READ	ELE.	RATE %	CUTS OR FILLS LEFT	℄	RIGHT
									Date
									Weather
	(Keep notes up the page)								Inst.
									Party

TOPOGRAPHY NOTES

STA.	T.P.	CONTOURS LEFT	℄	RIGHT	SKETCH ℄
					Date
					Weather
	(Keep notes up the page)				Inst.
					Party

OFFICE RECORD CROSS SECTION NOTES

STA.	ELE.	GRADE	CUTS OR FILLS LEFT	℄	RIGHT	END AREAS EXC.	END AREAS EMB.	CU. YDS. EXC.	CU. YDS. EMB.	REMARKS

37
93.

CHAPTER VI

PRELIMINARY ENGINEERING WORK

Under the heading of Preliminary Engineering Work is included all the work that is properly required to be done before the staking out of the work for the contractor is commenced. It is advisable also to do the following work early: make profiles and cross-sections of ravine sections, make soundings, look up shipping points and hauling routes, and determine a meridian.

RERUNNING THE LINE.- Rerunning the transit line consists in verifying the location notes by setting up the instrument over every transit point, or at least checking every transit point by sighting upon it, and checking in all stations for line and distance. The chaining should be carefully and accurately done, giving special attention to the measurement of plusses. Plumb bobs should be used when the ground is sufficiently broken to warrant it. The chainmen should carry the plumb bobs along, always, at least, attempting to hold the tape horizontal when chaining over rough and sloping ground. (See Consistent Errors on page 179). When necessary to "break chain", the tape should be carried out full length, then the head chainman should return to the proper place for breaking and after plumbing down to the exact point he should "thumb" the tape until the rear chainman comes up. No confusion of fractions will then result as the tape itself sums up the distances. The zero end of the tape should be carried ahead, and since the rear chainman reads the plusses and records them he should stand on the left side

of the line. He will then always read the figures right side up and will never have to subtract from one hundred, or stop long to figure out whether he should add or subtract the fractions of a foot. Distances should be measured from where the stake enters the ground and always from the same side of the stake. The location survey perhaps was hastily made, and the construction party should not take for granted that it is correct and check it upon such an assumption. If an error of a few tenths is discovered it should be noted. The tendency often is to call small differences "good enough" and go ahead without correcting or making note of them, then when the roadbed is finished and the line is rechained upon a smooth and practically level surface, the wonder is where the discrepancies came from!

All transit points should be checked for line by "double centering" or taking reverse sights, even though the transit appears to be in good adjustment, particularly upon long tangents, and all stakes should be set exactly upon line. Small angles in a supposed straight line may not show before construction, but after the roadbed is finished and the steel laid they stand out conspicuously, a good index to poor surveying. It takes a careful surveyor to run a straight line; anybody can run a crooked one.

If the Right of Way has been settled for upon the basis of the location survey, or other factors make it impossible to shift the line very much, the engineer should try to make the kinks or angles come at summits in the grade line where they will not be noticeable from either side of the summit. If the angle is sufficiently large the tangents should be connected by a curve. Before putting in a curve or making any radical changes, however, the discrep-

ancy should be reported to the chief engineer.

Curves should be rerun carefully and should also be recalculated, if necessary to make them check. Stakes are in general set every hundred feet on tangents, but on all simple curves it is suggested that they be placed every fifty feet except where the cuts or fills are very deep; in such cases they should be set every twenty-five feet for curves sharper than 10 degrees. (See table of middle ordinates under Staking Out Earthwork.) A habit that is always productive of carelessness and inaccurate checking is that of the rodman setting the rod upon the established point, instead of setting it to one side, and compelling the transitman to line it in. The allowable error or discrepancy is better measured at the hub as a chord intercepting the anguler error at the instrument, than measured by reading on the vernier the angle between the point lined in and the original point.

REFERENCE POINTS.- All hubs which are well located should be referenced carefully, the engineer keeping in mind the changed conditions that will result after construction begins and after grading is completed. Additional hubs should be set for convenience not over 1000 feet apart to avoid long journeys by the party in going from one transit point to another to give sights, also to give good definition of points sighted upon. Hubs close together are more easily sighted upon, and intermediate stakes may be set more accurately and more rapidly than if the backsights or foresights are far away. It is a time saver to put them in liberally. If additional transit points are established, they should be set by long foresights, if possible, so as to get them accurate and avoid little kinks in the line at every hub. The hub at the beginning and end

of each curve, the point of intersection, P. I., and the P. C. C., if spirals are used, should be referenced.

There are a number of methods of referencing the transit points. Perhaps the method most common in comparatively open and level or rollong country is that of fixing two lines at right angles to each other which will intersect at the hub to be referenced. It is convenient to establish these lines so as to make an angle of 45° with the center line.

The reference hubs are driven flush with the ground and a tack put in to mark the point, and a guard stake set a few inches back of the reference hub ~~and~~ projecting a foot or more above ground. The guard stake is usually marked R. P. (reference point) on one face and the station and plus of the hub referenced marked upon the other face. The distance out may be any convenient distance. A good place for a R. P. is about two feet inside of the Right of Way fence. This gives sufficient room to set up the transit, avoids the necessity of climbing the fence and prevents its being torn up by excavations for borrow pits. If the reference lines cannot be fixed 45° with the center line, then any angle may be chosen that will give the reference hubs a safe location. The angle between the two reference points should be kept as near 90° as possible. Prospective borrow pits, ditches, creek changes, blasting, buildings, camps, etc., must be considered in setting reference points.

Another method that the writer thinks worth mentioning is that of measuring out accurately about 15 or 20 feet each side of the hub to be referenced, preferably at right angles to the center line, and driving a hub on each side flush with the ground, guarding it with one, or preferably two, heavy stakes slanting toward

the point to be protected, and marked R. P., with the station number and distance out. This method can be used best at grade points or where excavations and embankmants are shallow. It is always convenient to have a hub on center line at a grade point, hence this method is suggested. The guard stakes must be unusually heavy and well set on account of the greater danger of their being torn up by the plows and graders when the cut is opened. The great advantage of this method of referencing is the short time that it takes to re-establish the centerline transit point, since only a tape is necessary. Especially is this an advantageous method when borrow pits excavated along the side of the roadbed become wet or filled with water, making a hub set near the fence inaccessable.

On side hill work, the reference points should generally be placed on the upper side of the roadbed where they are not so likely to be disturbed by blasting, or by rocks, rubbish, trees, brush, etc., being piled upon them. Spires, edges of buildings or chimneys, or a tack in a tree may often serve better than a hub for one of the points on each reference line. Good referencing is exceedingly important and requires good judgment and considerable foresight.

The exact plus to the nearest tenth of a foot should be obtained where the centerline crosses fences, property lines, section lines, road and street lines and banks of creeks. In general, all culture in any way connected with the railway line, for example, sheds, buildings, cultivated plats, drainages, roadways or drives, telephone poles, section corners, and perhaps even isolated trees, where traces of their location may be obscured when construction begins, should be located as accurately as consistent. A little

extra work and practical forethought in getting many rather than few details before they are obliterated will very often save argument, confusion and embarassment later. When such notes are recorded, careful sketching must be emphasized.

The position of objects adjacent to curves may be most easily and accurately located with reference to the sub-tangents.

All stakes should be carefully driven and plainly and properly marked. The rodmen should be cautioned against driving stakes promiscuously.

Any mistakes, discrepancies and equalities that are discovered in the re-running of the line should be properly recorded and reported to the chief engineer as soon as possible.

The reason for checking is to insure a reliable line upon which to stake out the work that comes later. Therefore, it must be done with much care, else errors will creep in before the work is finished through the repeated referencing in of hubs and the re-setting of stakes which have been disturbed.

If easement curves or spirals are required and are not put in by the locating party, they must be put in when the line is re-run. Their introduction will change the length of the line somewhat and therefore the plusses to the various objects along the line. All these detail changes must be reported to the chief engineer.

STAKING THE RIGHT OF WAY.- If the right of way has been arranged for and described with reference to the location survey, and if the resident engineer finds as he re-runs the line that the location survey is practically accurate, then it may be that the stakes, marking the boundaries of the right of way, may be set advantageously as the checking of the line proceeds.

The right of way or property line stakes should be good substantial stakes, preferably about the size of ballast stakes, I I/2" X I I/2" X 24" or 30", and should be set with tape and transit where the line changes direction, at offsets, at the beginning and end of curves, and on all summits. In general, they should be set close enough together so that any one stake may be sighted from the next with a transit. Stakes of the size indicated above driven down till firm in the ground with about one foot ptojecting will be found most satisfactory. They are easily seen, will serve as transit points, and are not likely to be mistaken for other forms of stakes. They should be marked "R. W." on the side toward the center line, and tacks set for marking the exact distance out. These stakes are usually only temporary marks but it is often several months before they are replaced by permanent monuments so they should be made substantial.

If left to project above the ground thay may serve as a guide to the fencing gang; but it is more usual to set smaller stakes for fencing purposes. These smaller ones should be lined in between the larger ones and spaced about 200 or 300 feet apart on tangents and 50 or IOO feet apart on curves.

The method outlined above is considered good practise, but if time will not permit the lining in of the stakes with a transit, for fencing, they may be measured in more quickly by chaining out at right angles from the center line on tangents or radially on curves. Right angles can be estimated with a little practise so closely that the slight deviation will not produce any appreciable error in the distance out. A deviation of 3.2 feet from the perpendicular at a distance of 50 feet from the center line would decrease the

actual distance out by only 0.I foot, which is closer than the fence is usually lined by the construction gang. The stake set should mark the outside of the fence, or the outside of the posts if wire is used, and not the center of the posts. The fence builder should be instructed concerning this point. Where stakes are required as guides in clearing only, the method of measuring out at right angles to the center line is sufficiently rapid and accurate.

Particular attention must be given to the setting of stakes for wing fences at road crossings. The company should furnish plans showing where, with respect to the sides of the road, they are to be placedespecially at oblique crossings.

Gates for farm crossings must also be marked plainly with stakes, consideration being given to the proper clearance for the gate. The location of such crossings should be looked into carefully. For grade crossings the gates should be placed near grade points when possible. For under -or over- crossings the approaches will be staked according to the plans for the special structure required.

Grade crossings should be avoided, and to this end study should be made of bridges or waterways with a view to making such necessary openings serve as cattle or stock passes.

CHECK LEVELS.- The check levels should be run ~~in~~ immediately following the re-running of the transit line and should be carried through into the adjoining residencies far enough to make sure that the datum used on both residencies is the same.

Rod readings should be taken directly in front of, and close to, every stake and at all breaks in the slope of the ground. The rod should be read to the nearest tenth of a foot without using the target. Turning points should be read to 0.00I foot with target, there be-

ing less likelihood of making blunders than if reading with a target to 0.0I foot. Special care should be taken to choose firm turning points, or to use an iron pin for this purpose. Using the top of stakes should be discouraged. Back sights and fore sights should be balanced, and, in general, none over 400' should be taken. With a "200 seconds to the inch" bubble tube, 0.I inch run of the bubble off from the center introduces an error of 0.039' in a 400' sight and a proportional error for other distances.

BENCH MARKS. - All bench marks along the line should be carefully checked and new ones added so that the distance between any two will not be more than I000 feet. There should always be a bench mark convenient to a grade point, near bridges and tunnels, and also near the site of buildings. Care must be taken, however, in the choice of their location so that, if near a grade point, the graders will not disturb it, or if near a bridge or building, material will not be piled over it.

Masonry footings and copings, bridge foundations, curbings, hydrants, foundation walls, large boulders, a nail in a tree root, or a spike in a tree or post, all suggest good forms of bench marks. If these are not to be found then stakes or hubs driven flush with the ground and properly guarded must be used. These latter are always in danger of being disturbed by the grading outfits or by frost and, therfore, must be frequently checked. Especially should they be checked if they have stood in the ground all winter and were subject to the effects of the frost. They are best located near the edge of the right of way close to the fence and on dry, well drained ground. When bench marks are made upon the root of a tree, they should be placed next to the center line so thay can be

readily seen from both directions. Time is saved by marking the elevation of the bench mark upon the guard stake, but the marking should always be verified by the instrumentman after it has been done; and always compared with his recorded elevation before he accepts it as a starting point for a new piece of work. The marking soon becomes weathered off and difficult to read and unless continually renewed and rechecked will be of little value.

The plusses to ordinary breaks in the slope may be carefully paced but plusses to creek channels and breaks at ravine sections should always be measured closely with a tape, since pacing at these points is likely to be difficult and unreliable. A foot or two in distance may be valuable in giving information needed to check the location of piling, piers, abutments, etc.

Elevations should be taken at the sides and center of highways, and the subgrade and base of rail at railway crossings, with exact plusses. The plusses recorded in the level book are a check upon those in the transit book when the notes are plotted. The profile of the centerline of highways should be taken for 500 or 1000 feet each side of the crossing; and the profile of base of rail taken at least 1000 feet each side of the crossing of ~~the~~ other railways.

If the bench marks do not check within the limit of error the reason should be sought. Perhaps there are evidences somewhere of their having been disturbed by frost, or in some other way, and if so no reliance should be placed upon them, but new ones must be established by carrying elevations from those which are reliable.

CHECKING WATERWAYS.- At the earliest convenience after the line and levels are checked, the drainage areas should be measured to determine in a general way the probable amount of water to be

carried across the roadway, and to assist in fixing upon the size of waterway required. Sometimes these areas are traversed by the locating party but are more often left for the resident engineer to measure. The locating party usually suggests the size of culverts and bridges from high water marks found at the crossing of the stream. Traversing the area, however, gives information not only of the size of territory drained but also of the slopes of the ground, kind of soil, vegetation, cultivation, and the probable changes due to clearing off the vegetation. Clearing the land of forests later may have a very important effect upon the size of the waterway to be provided. A knowledge of climatic conditions and information from old residents are often valuable. Since the areas do not have to be measured with accuracy, a line run with the compass and chain is often sufficiently good. If the declinition is known, the bearing of lines give absolute directions. Areas are readily calculated by latitudes and departures, or by plotting to scale and measuring the included area. There is no field check upon the work. Plotting gives the only check.

A better method is to run a stadia traverse, reading deflection angles or carrying azimuth, and checking with the compass. Distance is obtained directly by the stadia. In addition to the advantage due to checking angles, there is another advantage in the fact that only one rodman need be used. Backsights may be set up by the instrumentman, and the rodman sent ahead after setting a point to choose the next transit point upon the water shed. When distances are chained, the chaining cannot proceed with good results until the objective point ahead is chosen, therefore much more time is required than with the stadia.

The water shed should be traced from one point where it crosses the track to the point where it returns to the track, the railway forming the closing side of the area.

After the drainage area has been computed, the area of waterway in square feet is obtained from a formula or diagram.

Myer's formula or Talbot's formula are commonly used.

Myer's formula: $A = C\sqrt{\text{Acres.}}$ C = I.0 for gently rolling prairie, I.5 for hilly ground, 4.0 for rocky and mountainous country.

Talbot's formula: $A = C\sqrt[4]{(\text{Acres})^3}$. C = I/3 ± (+ for short valleys ∓ for long valleys) for rolling cultivated country subject to flood. C = 2/3 to I, for steep and rocky ground.

On a prominent southern road the following values for C were given for Talbot's formula: C = I.0 for very steep ground; C = 3/4 for rolling ground.

Usually the more reliable way of determining the waterway required is to observe floods, note evidences of extreme high water marks and learn if possible the velocity of the stream, then measure the high water cross-section or profile along the center line of the road. The area need not always be made equal to the area of such a cross-section since the water may often be backed up or made to flow under head without danger to the roadbed, particularly if winged culverts or culverts with large head walls be used, and also if adjacent territory on the upstream side is large and comparatively level. If the ground is steep and the water has a high velocity, the area of the waterway may not be diminished with safety much below the area of the high water section. Consideration must also be given to possible damages to property resulting from back water. The probable frequency of floods in any particular region

may also be a pertinent matter.

The choice of size and kind of bridge or culvert is a matter of good judgment only, since there are no definite rules to be followed. If there is any great possibility of an error being made, an endeavor should be made to keep it on the side of safety. It is a good rule never to make a culvert with an area of less than 9 square feet. The height of the culvert should not be less than the width unless the height of the embankment will not permit of these proportions.

Of the principal agents of destruction, decay, frost, and water, the last is the most dangerous and formidable. Its action is often most sudden, unexpected and violent.

Evidences of high water must be sought for persistently. After hard rains or during the season of melting snow, trips should be made over the line to observe and to mark the high water lines. The usual evidences to be looked for are regular, horizontal lines of erosion upon vertical banks, grass matted together by deposited material, grass or debris clinging to brushes and fences, and dirt deposited on the upstream side of trees and posts. The search should be far reaching and in unexpected places. The writer recalls as evidence of high water along a large stream in a mountainous country, a large rail deposited in the fork of a tree nearly forty feet above normal water level, and unless pointed out by an old resident would not have been noticed. In an extreme case of this kind the railway company would take chances to a certain degree and probably never place their lowest bridge chord above that high elevation. Another instance is recalled of a flood which occurred in a heavily timbered country, comparatively level, where

even the "old inhabitant" was suprised. A bridge that was designed to be well above the highest high water mark that could be discovered, would have been almost submerged had it been erected before the flood came.

Good drainage and careful consideration of the effects of water cannot be impressed too strongly upon the resident engineer.

RAVINE SECTIONS.- The work of making profiles of high water cross-sections consists in making an accurate profile along the centerline of the railway, of the ground covered by the flood water, including the flats on either side of the channel as well as the channel itself. Note should be made of high water elevations, of all obstructions such as grass, bushes, trees, rocks, etc., and their location along the profile.

The area of the high water profile may be readily calculated by "Simpson's I/3 rule", or the profile may be plotted to a large scale on cross-section paper and the rectangles in the area of the profile counted to give the area with sufficient exactness.

Simpson's Rule:

Area = A = D/3 [f + l + 2(sum of odd numbered ordinates) + 4(sum of even numbered ordinates)]. D = distance between ordinates. f = first ordinate. l = last ordinate. f and l are not included in the sums of even and odd ordinates.

A survey of a ravine section is made for the purpose of choosing the kind of structure, its dimensions both longitudinally and transversely, and the best location. The field work consists of obtaining a profile along the centerline across the channel and well up the banks on either side, including the high water profile and a little more; also profiles parallel to the centerline and about

IO feet from it on each side. These three profiles are plotted upon the same sheet of cross-section paper to a scale of one inch equals ten feet both vertically and horizontally. A drawing of this scale serves for plotting trestle bents and estimating piling and timber required. For bridge abutments, piers and wide structures, a drawing showing the contours is better. To make this contour map cross-sections are taken about every ten feet along the line and out to the limits of the right of way transversely, so that contours may be plotted accurately, using a one-foot or two-foot interval. The map is plotted to a scale of one inch equals ten feet. The profiles and contours are often shown on the same cross section sheet, paper "IO X IO to one inch" ruled in blue being commonly used; or if blue prints are desired, the transparent cross section paper "IO X IO to one inch" printed in orange is suggested.

A complete drawing of a ravine section should contain the plan and profile of the ground, the alinement of the track, the grade line, the right of way lines, the orientation of the drawing, the limits of the high water area and high water profile, the limits of the normal stream or water lines in both plan and profile, and the direction of the stream indicated by an arrow.

Notes should be printed on the sheet giving the area of high water, drainage area, and estimated size of water way, information concerning the soil, foundations, etc. A letter accompanying the drawing should suggest the locations for the structures as proposed by the resident engineer.

SOUNDINGS.- Where bridge structures of considerable size and requiring deep or unusually good foundations are to be built, careful investigations must be made. The structures can then be prop -

erly designed and the estimates of materials intelligently made. Even for small culverts it is well to make soundings if there is any probability of a soft or uncertain foundation, since it is much less expensive to make the soundings than it is to tear out and rebuild a culvert that has been imperfectly located. Such an unfortunate circumstance is likely to reflect upon the judgment of the engineer, although he may have done his best so far as choosing the best apparent site was concerned. Surface indications are not always reliable and soundings or borings should be resorted to whenever practicable.

For soundings where a sample of the material is not important and only the resistance of the material is desired, a blunt pointed iron rod one half inch in diameter is often sufficient and may be satisfactorily used in soft ground to a depth of 15 or 20 feet. For greater depths some special form of rod must be used. One form of rod that is quite satisfactory is made of five-foot or six-foot lengths of 3/4 inch, or one inch, hollow rods threaded inside at one end so that a smooth joint is made when the rods are screwed together. The penetrating point may be a chisel welded into the end of a rod. On the end of another rod may be screwed a two-or four-way section so that handles may be inserted at right angles to the rod and two or four men may work in pushing the rod down or pulling it up. As the rod enters the ground additional lengths are screwed on. This form of rod has been used successfully in soft material to depths of thirty-five or forty feet.

Where the underlying material is uncertain, soundings should be taken close together and over an area that will fully include the base of the structure. Some practice, or at least good judgment

at the upper end of the rod, is necessary to interpret soundings correctly. A small pebble firmly bedded may resist the rod and give the impression of a boulder or solid rock. Open test pits give absolute certainty as to the nature of the material encountered,but they cannot be dug to a greater depth than eight or ten feet easily and may not be feasible at all where the ground is wet.

Augers break rather easily and are difficult to turn or keep sharp especially where there are pebbles.

BALLAST PITS.- The resident engineer should keep in mind the need of good ballast and by inquiry and investigation determine whether any gravel beds, rock quarries, cinders, furnace slag piles, burnt shale from coal mines, chats, etc., are available.

Gravel of good quality is frequently found in large quantities in or along creek channels. In glacial areas it is to be sought in hills. That along creeks must be loaded by hand shoveling while that in hills may be most economically loaded by machinery. Due consideration must be given to the cost of opening up a gravel pit or stone quarry, and test pits should be dug to ascertain the quality and amount probably available. The cost of stripping, cost of plant, cost of building roads,and cost of operation are all very significant and require that the supply be large to justify working the pit.

It often happens that ballast can be brought in over the main line much more cheaply than local pits can be worked. There are, however, always possibilities of supplies close at hand and the resident engineer should make investigations and report the result of his observations to the chief engineer.

WATER SUPPLIES.- Water supplies along the line should be invest-

igated with the view of obtaining both temporary and permanent supplies.

Temporary supplies are required by the railway company principally for the locomotives used during track laying, and for boarding cars. It is well to take note of any sources that can be utilized by the contractor for steam shovels, rock drilling plants, camp, etc.

The permanent supplies are those that will be needed after the track is completed and put in operation. They may prove to be important considerations in the choice of station sites, side tracks, and yard locations. It is an economy in operation to have a water station convenient to a passing track so that a locomotive may take water while waiting for another train.

Sources of supply may be found in springs, creeks, lakes and reservoirs. Attention must be paid to the quantity available, also to the quality. Sights for dams to impound water during dry seasons should be investigated. These are suggestions of what may come within the province of residency work.

TIMBER SUPPLIES.- If the road has no regularly employed timber cruiser or inspector, the resident engineer may have to give some of his time to looking up the local supply of timber. The company sometimes furnishes timber for temporary structures and whenever possible will obtain it along the right of way. For these structures it matters less whether the timber be oak, pine, spruce, cedar, elm or hemlock than whether it be sound. For permanent structures the company specifications will govern the selection of timber. Usually, however, the resident engineer will only need to report upon the kind and amount of timber available.

SHIPPING POINTS.- The chief engineer and superintendent are familiar with freight rates upon construction material, and the best and cheapest routing, and can therefore choose the best shipping points. The resident engineer's knowledge, however, of the places for distribution of material along the line, the best routes by which it can be hauled to the line, and the best sites for storage yards, will warrant him in making suggestions as to the proper shipping points. He may have to provide for storing stone, sand, cement, draintile, culvert pipe, bridge iron, reinforcing bars, etc., and probably ties, rails and other track material. Much room will be required, and proper housing of some of the materials will be necessary. If stored for any great length of time, consideration must be given to the accessibility of wagons for loading, the road ways, and sequence of piling with regard to the time when it will be used.

ROUTES FOR HAULING MATERIAL.- The resident engineer should determine the best and shortest route for hauling material to the place on the line where it is to be used. Materials are hauled for a certain price per ton mile so the shortest route is the cheapest, other things being equal. The shortest may not always be the best, however, and the engineer should be reasonable in his specifications as to which routs the contractor must use. If the short route is muddy or in such condition as to be practically impassable while the longer route is in good condition, and the material is required before the short route becomes useable, then the longer route should be permissable and payment made for the longer haul. If the short route were bad only in spots and these could be crossed by "doubling" teams, perhaps it would not be unreasonable to re-

quire this route to be used. The option might be given the contractor to use either route with payment based on the shorter. Such an option should be reduced to writing, however, or the resident engineer may find it necessary to pay on the basis of the actual route used.

CONSULTING PROPERTY OWNERS.- Before giving stakes for the beginning of a piece of work, the resident engineer should convince himself that all rights of the property owners have been settled or arranged for by the right of way agent. If not arranged for he may be forbidden to set stakes. The contractor sometimes takes for granted that all differences between the property owners are settled and he enters the property and sets up camp without leave of the property owner. Even though no damage is done, the taking possession of his land disgruntles him-perhaps justly-and he does not forget his injury as long as the construction continues. On the other hand, actual damage may be done by the contractor. He cuts a fence and leaves the gates open, the farmer's stock gets out and his regular farm routine is demoralized. All of these perplexities may be avoided if the engineer calls upon the property owner. He can usually make some arrangement pending the company's action. Even though all arrangements have been made and all parties are satisfied, it is well and proper to give the property owner notice of the time when the work will begin. It is only fair, and he will appreciate it.

DETERMINATION OF A MERIDIAN.- It is very desirable that a meridian be determined at some convenient point on the residency and from it absolute direction or bearings of the various tangents calculated. Usually, the engineer is instructed to perform this

work, but, strange to say, very little information is ever suggested as to how it should be done, and the necessary tables are seldom furnished. The presumption is that the resident engineer has the tables and understands the process when the contrary is more likely the case.

If the residency is only a few miles long a determination at one point will suffice, but if it is several miles long it is well to determine a meridian at both ends. If there are well monumented and reliable section corners established in the vicinity of the railway line, tie lines connecting the section lines with the railway line will make it possible to obtain the orientation of the tangents with respect to north and south. The section corners as usually marked are too often unreliable and very frequently are not to be found at all, so the safest method is to make an independent determination by observation upon the sun or stars. Although there are numerous methods of observation, those given below are recommended as being simple, easily and quickly performed, and sufficiently accurate for the purpose.

AZIMUTH FROM OBSERVATION UPON POLARIS AT OR NEAR ELONGATION.- From the table choose the most convenient time of elongation.

Everything should be in readiness a few minutes before the time for taking the observation. Get Polaris in the field of view and keep it in line with the vertical wire by use of the slow motion screw. At the exact time of elongation or when the star ceases to move horizontally, plunge the telescope and set a hub and tack about three or four hundred feet away. To eliminate instrumental errors, quickly reverse the telescope, set the vertical wire in line with the star again, and set another tack, if necessary; then

fix a point midway between the two tacks. The azimuth of Polaris at elongation, that is, the angular deviation from the true north, of the line just established, may be calculated or taken directly from the table, then at any convenient time this azimuth may be set off with the transit to find the true meridian. Lay off the azimuth to the left, or west, if the observation was made at eastern elongation; to the right, or east, if the observation was made at western elongation.

The azimuth of Polaris for years 1909 to 1920 are given in the table page 66; the azimuth may be computed by the following equation. $\text{Sine of Az. of Polaris} = \dfrac{\text{Sine of Pole Distance}}{\text{Cosine of Latitude of Observer}}$

A variation of this method of observing Polaris for azimuth, which gives the observer a wider range of time for making the observation, is performed as follows:

The star is observed at any time within about an hour of elongation and the exact time of observation recorded. The azimuth of Polaris is computed or taken from the table and the following correction "c" is applied: $c = 0.058t^2$ in seconds of arc. t = difference in minutes of time between the time of elongation of Polaris and the recorded time of observation. The constant 0.058 is used in Latitude 40°; for Latitude 30° use 0.052; for Latitude 50° use 0.069; and interpolate between these values for intermediate latitudes. The correction c should be added to the computed, or table, azimuth of Polaris when observed at west elongation, and subtracted from the computed, or table, azimuth when observed at east elongation.

The time of elongation is given in the table for the civil day. The table is worked out for Longitude 90° W. and Latitude 40° N.

Since longitude and latitude affect very slightly the time given in the table, their correction may be neglected in the United States. The local time must, however, be calculated. If the observer's watch is keeping standard time, as it usually is, and the place of observation is east of the standard meridian by whose time the watch was set, then elongation comes earlier as timed by the watch; if the place of observation is west of the standard meridian, elongation comes later as timed by the watch. If the observation station is Longitude 96°-30', then the correction, which is four minutes of time for every degree of longitude, is 26 minutes. If the elongation as given in the table for Jan. 19, 1909 is 12-47.5 P.M., then the observer's watch should read (12 hr.-47.5 min. + 26 min.) 1 hr. 13.5 min. P.M. The longitude may be estimated within a fraction of a degree from railroad or county maps, or it may be obtained from the chief engineer's office. The list of base lines and principal meridians, together with an outline of the territory governed by them, will serve this purpose for those parts of the United States which have been subdivided by the government. (See the accompanying map and sketches on pages 67, 68, 69).

DETERMINATION OF A MERIDIAN BY OBSERVATION UPON THE SUN AT EQUAL ALTITUDES.- The transit is set up over a point on the line, carefully levelled and a pointing made upon the sun about middle forenoon. The altitude or vertical angle is read when the horizontal wire is tangent to the limb, and a hub and tack set on line with sun at that moment a few hundred feet away. In the afternoon before the sun has descended to the altitude observed in the morning, the transit is set up again, the vernier on vertical arc set at exactly this altitude. The observer points the telescope in the direction

of the sun and when it comes into his field of view he follows it with the horizontal motion. At precisely the time when the sun's image is bisected by the vertical wire and tangent to the horizontal one, the horizontal motion is clamped and a hub and tack set on this line. If the declination of the sun did not change, a line bisecting the angle between the line fixed in the forenoon and the one fixed in the afternoon would be a true north and south line. Since the declination changes, the following correction must be made:

D = total change in declination in minutes from A.M. observation to P.M. observation.

ϕ = Latitude of observer.

T = time between observations expressed in degrees of arc. i.e., 1 hour = 15°.

Correction = $\dfrac{1/2\ D}{\text{Cos}\ \phi\ \sin T/2}$ in minutes of arc.

Correction is applied from south toward the west from June 21st to December 21st when the declination is decreasing, and from south toward the east from Dec. 21st. to June 21st when the declination is increasing. The declination may be obtained from the ephemeris supplied by instrument makers.

This method of equal altitudes may be applied to circumpolar stars, in which case no correction for declination is necessary. The line bisecting the angle between the two equal altitude observations is a true meridian. Care must be exercised in choosing a star that can be easily recognized again for second observation. A star 30° or 40° from the pole is suggested.

DETERMINATION OF LATITUDE.- If the latitude of a place is unknown it may easily be determined by an observation upon Polaris at eihter upper or lower culmination, or upon the sun when it reaches its maximum altitude.

Observation upon Polaris at Culmination.- From the table, P.65, find the time of culmination of the star, reduce this time to the time kept by the watch as explained in determining azimuth. Set up the transit, level carefully, make a pointing upon the star at the proper time, and read the vertical angle. A reverse reading should be taken to eliminate errors in adjustment of transit. The vertical angle corrected for pole distance and refraction gives the latitude, as indicated in the formula accompanying the sketches.

As in observing for azimuth, if the observation is not taken at culmination but within an hour or less, either before or after culmination, a correction may be applied to the vertical angle to get the altitude of the star at culmination.

Correction = 0.0444(minutes of time from culmination)^2, in seconds of arc. Add this correction to the observed angle if the observation is made near upper culmination, and subtract if made near lower culmination.

The Pole Distance is subtracted from the altitude at upper culmination and added to the altitude at lower culmination to give the altitude of the North Pole itself.

Refraction correction is always subtracted to give the true altitude of a star.

Observation upon the Sun at Noon.- Read the vertical angle to the center of the sun, or better, take the average of reverse readings, one on the upper limb, the other on the lower limb of the sun, when it reaches its highest altitude, which is about noon. By following the sun with the horizontal wire, it can easily be ascertained when it ceases to rise higher; the vertical angle of this maximum altitude is then read.

The altitude of the celestial equator is 90° - (latitude of the observing atation).

To find the altitude of this equator, the declination of the sun must be subtracted from the altitude of the sun from March 22 to Sept. 22, and added to the altitude of the sun from Sept. 22 to Mar. 22.

The correction for refraction must be subtracted from the observed vertical angle to give the true altitude of the sun. Latitude then equals 90° minus the observed vertical angle plus refraction angle plus the declination from March 22 to Sept. 22, or minus the declination from Sept. 22 to March 22. The formula and sketches will make this method clear.

With careful manipulation of the instrument the methods given above for determining both azimuth and latitude should give results to the nearest minute of arc, which is as close as the vernier of the usual field transit reads.

The observations upon Polaris are preferred. The high altitude of the sun in summer makes a determination of the latitude practically impossible with the ordinary transit. Direct sighting upon the sun is impossible. If there is no reflecting eye piece with dark glass with the instrument, then an image of the sun may be obtained upon a piece of white paper held a few inches back of the eye piece. Careful focussing will give a sharp image of the sun and cross hairs.

The declination of the sun may be taken from the Solar Ephemeris supplied by instrument makers. Correction must be made for local time. Subtract from watch time if east of Standard Principal Meridian; add if west.

When the telescope is sighted upon only one limb of the sun, the pointing may be reduced to the center of the sun by applying a cor-

rection for the sun's semi-diameter, about I6 minutes of arc.

A list of the Principal Meridians and Base Lines of the United States are given, together with their longitudes and latitudes respectively. From this information, and knowing the sections, townships, ranges, etc., through which the railway line passes, the longitude and latitude of any points on the residency may be quite closely calculated. An outline of the principal divisions of the United States for standard time is also given and from this, knowing the longitude, the local time can be calculated and compared with watch time.

The standard-time meridian is theoretically the middle of the time belt, that is, the change of time is made half way between two adjacent meridians. The actual limits of the time belt are irregular, being fixed by division points, junctions and railroad terminals.

ELONGATIONS & CULMINATIONS OF POLARIS IN 1909

LAT. 40°N. LONG. 90°W.

DATE		ELONG. EAST	ELONG. WEST	CULM. UPPER	CULM. LOWER
		h m	h m	h m	h m
JAN	1	12 47.5 P.M.	12 40.4 A.M.	6 42.5 P.M.	6 44.5 A.M.
	15	11 52.2 A.M.	11 42.2 P.M.	5 47.2 "	5 49.2 "
FEB	1	10 45.1 "	10 35.1 "	4 40.1 "	4 42.1 "
	15	9 49.8 "	9 39.8 "	3 44.8 "	3 46.8 "
MAR	1	8 54.6 "	8 44.6 "	2 49.6 "	2 51.6 "
	15	7 59.4 "	7 49.4 "	1 54.4 "	1 56.4 "
APR	1	6 52.4 "	6 42.4 "	12 47.4 P.M.	12 49.4 A.M.
	15	5 57.4 "	5 47.4 "	11 52.4 A.M.	11 50.4 P.M.
MAY	1	4 54.6 "	4 44.6 "	10 49.6 "	10 47.6 "
	15	3 59.6 "	3 49.6 "	9 54.6 "	9 52.6 "
JUNE	1	2 53.0 "	2 43.0 "	8 48.0 "	8 46.0 "
	15	1 58.2 A.M.	1 48.2 P.M.	7 53.2 "	7 51.2 "
JULY	1	12 55.5 A.M.	12 45.5 P.M.	6 50.5 A.M.	6 48.5 P.M.
	15	11 56.8 P.M.	11 50.7 A.M.	5 55.7 "	5 53.7 "
AUG	1	10 50.2 "	10 44.2 "	4 49.2 "	4 47.2 "
	15	9 55.4 "	9 49.3 "	3 54.3 "	3 52.3 "
SEP	1	8 48.8 "	8 42.7 "	2 47.7 "	2 45.7 "
	15	7 53.9 "	7 47.8 "	1 52.8 "	1 50.8 "
OCT	1	6 51.1 "	6 45.0 "	12 50.0 A.M.	12 48.0 P.M.
	15	5 56.1 "	5 50.0 "	11 51.1 P.M.	11 53.0 A.M.
NOV	1	4 49.3 "	4 43.2 "	10 44.3 "	10 46.2 "
	15	3 54.1 "	3 48.1 "	9 49.1 "	9 51.1 "
DEC	1	2 51.1 "	2 45.0 "	8 46.1 "	8 48.0 "
	15	1 55.9 P.M.	1 49.8 A.M.	7 50.9 P.M.	7 52.8 A.M.

TO USE THE TABLE

FOR INTERMEDIATE DAYS OF THE MONTH

No. of Days Elapsed	Day of Month	Minutes
1	2 or 16	3.9
2	3 " 17	7.9
3	4 " 18	11.8
4	5 " 19	15.7
5	6 " 20	19.6
6	7 " 21	23.6
7	8 " 22	27.5
8	9 " 23	31.4
9	10 " 24	35.4
10	11 " 25	39.3
11	12 " 26	43.2
12	13 " 27	47.2
13	14 " 28	51.1
14	29	55.0
15	30	58.9
16	31	62.9

Note: When computing from a PRECEDING date SUBTRACT the minutes. When computing from a FOLLOWING date ADD the minutes.

FOR OTHER YEARS THAN 1909

For 1910 add 1.2 Minutes
1911 " 2.5
1912 " 3.9 Up to Mar. 1st.
1912 " 0.0 On & after "
1913 " 1.4
1914 " 2.8
1915 " 4.3
1916 " 5.8 Up to Mar. 1st.
1916 " 1.9 On & after "
1917 " 3.5
1918 " 5.1
1919 " 6.7
1920 " 8.3 Up to Mar. 1st.
1920 " 4.4 On & after "

CORRECTION for LATITUDE

30°N. to 40°N. ADD to West Elong. or SUBTRACT from East Elong. 0.14 minute per degree south of 40°N.
40°N. to 50°N. SUB. from " " " ADD to " " 0.18 " " " north " 40°N.

J.E.S.

POLE DISTANCE OF POLARIS

MONTH	1909	1912	1915	1918	1921
	YEAR				
JAN	1°-10.8'	1°-09.8'	1°-08.9'	1°-08.0'	1°-07.0'
FEB	1-10.9	1-09.9	1-09.0	1-08.1	1-07.1
MAR	1-11.0	1-10.0	1-09.1	1-08.2	1-07.2
APR	1-11.1	1-10.1	1-09.2	1-08.3	1-07.3
MAY	1-11.3	1-10.3	1-09.4	1-08.5	1-07.5
JUNE	1-11.4	1-10.4	1-09.5	1-08.6	1-07.6
JULY	1-11.5	1-10.5	1-09.6	1-08.7	1-07.7
AUG	1-11.4	1-10.4	1-09.5	1-08.6	1-07.6
SEP	1-11.3	1-10.3	1-09.4	1-08.5	1-07.5
OCT	1-11.1	1-10.1	1-09.2	1-08.3	1-07.3
NOV	1-11.0	1-10.0	1-09.1	1-08.2	1-07.2
DEC	1-10.9	1-09.9	1-09.0	1-08.1	1-07.1

Interpolate for other dates

MEAN REFRACTION CORRECTION FOR VERTICAL ANGLES

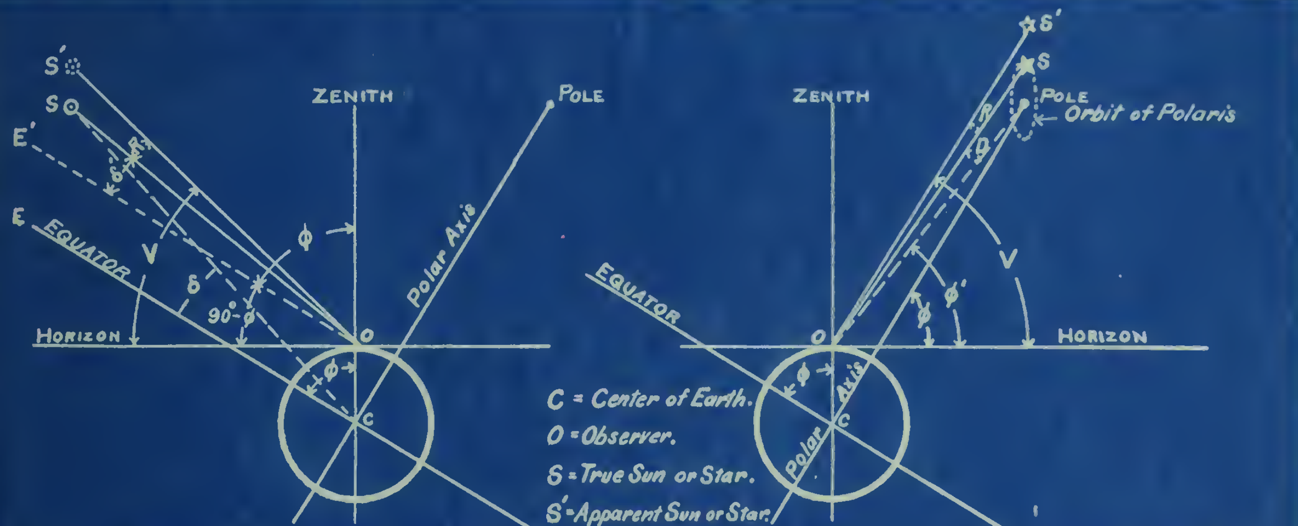
Alt.	Ref. minutes	Alt.	Ref. minutes	Alt.	Ref. minutes
10°	5.32	22°	2.39	40°	1.16
12	4.46	24	2.17	45	0.97
14	3.82	26	1.98	50	0.81
16	3.34	28	1.82	60	0.56
18	2.96	30	1.68	70	0.35
20	2.65	35	1.38	80	0.17

AZIMUTH OF POLARIS 1909

LATITUDE	AZIMUTH	FACTOR minutes
30°N.	1°-21.7'	0.35
31	1-22.5	0.36
32	1-23.4	0.36
33	1-24.3	0.37
34	1-25.3	0.37
35	1-26.4	0.38
36	1-27.5	0.38
37	1-28.6	0.39
38	1-29.8	0.39
39	1-31.0	0.40
40	1-32.4	0.41
40	1-33.8	0.43
42	1-35.2	0.43
43	1-36.8	0.43
44	1-38.4	0.44
45	1-40.1	0.44
46	1-41.9	0.45
47	1-23.7	0.45
48	1-45.8	0.46
49	1-47.9	0.47
50	1-50.1	0.48

NOTE: For years following 1909, multiply the difference between 1909 and the given year by the FACTOR for the given Latitude and SUBTRACT the product from the Azimuth for 1909.

Azimuth may be computed from this formula: $\text{Sine Azi.} = \dfrac{\text{Sine Pole Distance}}{\text{Cosine of Latitude}}$



E'O is parallel to EC, or practically coincident.

δ = Declination of the Sun = Angular distance above or below the Equator = practically δ'.

S "crosses the line" EC Mar. 22 and Sep. 22.

V = Altitude of Apparent Sun.

$\phi = 90° - (V - \delta - R) = 90° - V + \delta + R$ for N. Dec.

$= 90° - V - \delta + R$ " S. Dec.

R = Angle of Refraction.

V = Vertical angle as observed.

φ = Latitude of Observer.

OS practically parallel with CP.

φ' is practically equal to φ

D = Pole Distance of Star

$\phi' = V - R - D$ for Upper Culm.

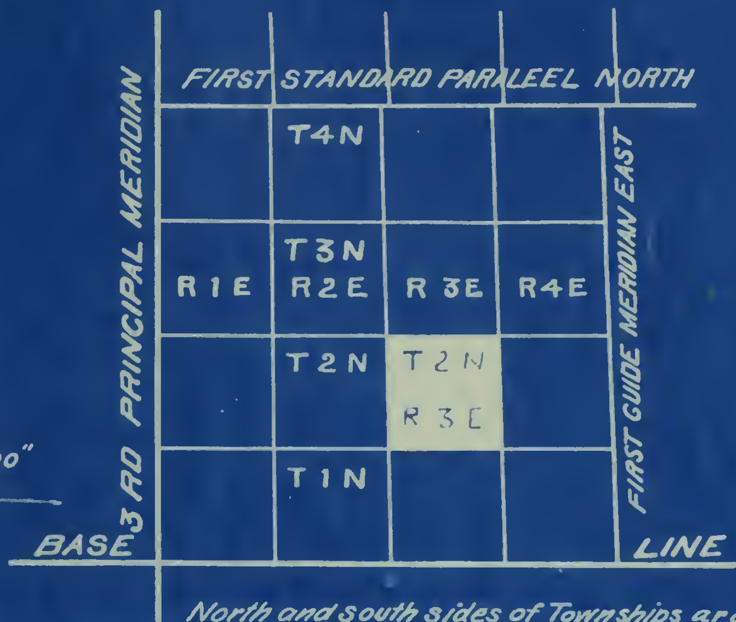
$\phi' = V - R + D$ for Lower Culm.

DIAGRAMS SHOWING LATITUDE OBSERVATIONS

J.E.S.

STANDARD TIME BELTS OF THE UNITED STATES

NAME	CONVENTIONAL COLOR	MERIDIAN	GREENWICH NOON
Colonial	Brown	60° West	8 O'clock A.M.
Eastern	Red	75 "	7 " "
Central	Blue	90 "	6 " "
Mountain	Green	105 "	5 " "
Pacific	Yellow	120 "	4 " "



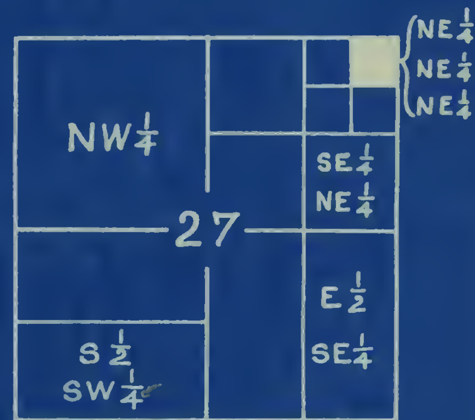
North and south sides of Townships are parallel to the Standard Parallels.

East and west sides (Range Lines) are true north and south lines (Meridians)

Convergence of Range Lines may be found as follows: The cosines of the latitudes are to each other as the lengths of the intercepted parallels.

These lines are parallel to the East boundary of the Township

T. 2 N., R. 3 E.



SECTION 27

Description of Shaded part is

NE¼, NE¼, NE¼, Sec. 27, T. 2 N., R. 3 E., 3 P.M.

RECTANGULAR SYSTEM U.S. SURVEYS

J.S.

MERIDIANS AND BASE LINES OF U.S. SURVEYS

PRINCIPAL MERIDIANS	WEST LONGITUDE ° ′ ″	RUNS NEAR–	BASE LINES	NORTH LATITUDE ° ′ ″	RUNS NEAR OR WITH–
FIRST	84 48 50	Ohio State line.			Findlay, Ohio.
SECOND	86 28 00	Lebanon, Ill. & Indianapolis.		38 28 20	Salem, Ind.
THIRD	89 10 15	Cairo, Ill.		38 28 20	Centralia, Ill.
FOURTH	90 28 45	Plattville, Wis. & Rock Island, Ill.		{ 42 30 00 40 00 30	State Line, Wis. Beardstown, Ill.
FIFTH	91 03 42	Powhatan, Ark. & Dubuque, Iowa.		34 44 00	Little Rock, Ark.
SIXTH	93 23 00	Wichita, Kan. & Columbus, Neb.		40 00 00	On State Line.
MICHIGAN	84 22 24	Lansing, Mich.	MICHIGAN	42 26 30	Detroit.
TALLAHASSEE	84 16 42	Tallahassee, Fla.	TALLAHASSEE	30 28 00	Tallahassee.
ST. STEPHENS	88 02 00	Mobile, Ala.	ST. STEPHENS	31 00 00	State line.
HUNTSVILLE	86 34 45	Huntsville, Ala.	HUNTSVILLE	35 00 00	North State line.
CHOCTAW	90 14 45	Jackson, Miss.	CHOCTAW	31 54 40	Hazelhurst.
CHICKASAW	89 15 00	Holly Springs, Miss.	CHICKASAW	34 59 00	Old Tennessee boundary.
WASHINGTON	91 09 15	Natchez, Miss.	ST. STEPHENS	31 00 00	State line.
ST. HELENA	91 09 15	Baton Rouge, La.	"	31 00 00	" "
LOUISIANA	92 24 15	Alexandria, La.	"	31 00 00	" "
NEW MEXICO	106 53 40	Socorro.	NEW MEXICO	34 15 25	Socorro.
NAVAJO	108 32 45	New Mexico & Arizona.	NAVAJO	35 45 00	
SALT LAKE	111 54 00	Salt Lake City, Utah.	SALT LAKE	40 46 04	Salt Lake City.
UINTAH	109 57 30	Utah.	UINTAH	40 26 20	
BOISE	116 24 15	Boise City, Idaho.	BOISE	43 22 31	Idaho Falls.
MOUNT DIABLO	121 54 48	San Jose, Cal.	MOUNT DIABLO	37 51 30	San Francisco.
HUMBOLT	124 08 00	Eureka, Cal.	HUMBOLT	40 25 12	Cape Mendocino.
SAN BERNARDINO	116 56 15	San Diego, Cal.	SAN BERNARDINO	34 07 10	San Bernardino.
WILLAMETTE	122 44 20	Portland, Ore.	WILLAMETTE	45 31 00	Portland, Ore.
BLACK HILLS	104 03 00	Wyoming boundary.	BLACK HILLS	44 00 00	Rapid City.
MONTANA	111 38 50	Helena.	MONTANA	45 46 48	Billings.
GILA & SALT RIVER	112 17 25	Phoenix, Arizona.	GILA & SALT RIVER	33 22 40	Phoenix.
INDIAN	97 14 30	Guthrie, Oklahoma.	INDIAN	34 30 00	Duncan.
CIMARRON	103 00 00	New Mexico boundary.	CIMARRON	36 30 00	Texas boundary.

J.E.S.

Condensed from Manual of Surveying Instructions

CHAPTER VII

STAKING OUT THE WORK

"Keep good records and never let a contractor have reason to call for stakes more than once" was the advice given by a chief engineer to a resident engineer about to take up the work on his first residency. Stakes are the guides by which the honest contractor performs his work. Therefore to execute it properly and to specifications, they must be set carefully and accurately. Not only is this necessary so far as the contractor is concerned, but it is equally important to the engineer himself. All work that can possibly be staked out should be so defined. It is better to have a few more stakes set than necessary, provided they are in the proper place and will not lead to confusion, than to have so few stakes that the contractor must guess at his work, or perhaps must do it from verbal instructions. Stakes well set are the engineer's defense.

CLEARING.- In a wooded country, the first construction stakes to be set are those for marking the limits of clearing. As mentioned before, it may be found convenient to set these stakes while the centerline is being rerun, providing the limits of right of way have been settled at that time. If stakes are set for clearing only, they should project at least one foot above the ground and the letters "R.W." printed upon the side facing the center line. Where the timber or underbrush is dense, they can be measured out most conveniently at right angles from the center line; under such conditions they should be set about 200 feet apart on tangents and

IOO feet on curves, ~~and~~ at all offsets, and at P.C. and P.T. of curves.

It is of little use to set axcavation stakes before the right of way is cleared, but it is sometimes considered economy of time to cross section the work before the clearing is finished and then measure in the stakes afterward from the records. This procedure may be advisable in the open but it is unreliable in wooded country.

The limits of grubbing cannot be indicated until after the earthwork is staked since the earthwork stakes fix these limits. All cuts, borrow pits, channels and bridge sites must be grubbed; also the area under embankments up to a specified height.

EARTHWORK.- Cross sections should be taken at all breaks in the slope of the natural ground, and should be carried out to the limits of the right of way wherever it is probable that borrow pits or channels will be excavated along the side of the road bed. Where the ground is not irregular, cross sections every IOO feet on tangents are sufficiant. Where the ground is sloping, sections should be taken sufficiently close so that the difference in center heights between any two adjacent sections will not be greater than three feet, to insure close results when volumes are calculated by the average end area method. At grade points between embankments and excavations, at least three sections should be taken, one at the plus of the grade point on the center line, one at the plus of the grade point on the right and one at the plus of the grade point on the left.

It is advisable to set stakes at every cross section unless there are so many as to give rise to confusion. On rough ground

sections must be taken at frequent intervals to give close results when volumes are calculated; and since the intersection of the slope of embankment with the ground will form a very irregular line, it is, therefore, necessary for the contractor to have stakes also at practically every section in order to properly build up his slopes. On curves ~~and~~ cross sections stakes should be set often enough to give a slope line that will appear as a curve and not a succession of chords, particularly in heavy work. It is suggested that slope stakes be set every 50 feet on all curves up to curves of 10°. The following table gives the middle ordinates of 5°, 10° and 20° curves for 100 foot, 50 foot and 25 foot chords and will aid in choosing the distance between cross sections for the given curves.

Degree	Chord		
	100'	50'	25'
5°	1.09	.27	.07
10°	2.18	.54	.14
20°	4.37	1.09	.27

A cross section should be taken, and stakes set, at the P.C. and P.T. of the curves, and if spiraled, at the end of each chord in the spiral.

Grade compensation for curvature is calculated before the profiles are sent to the residency and therefore taken into account in the rates of grade shown on the profile.

Vertical Curves.- The calculation of vertical curves should be checked before the curves are cross sectioned. The railway company will usually specify the length of vertical curve to be used. Some roads use a universal length of curve on both summits and

sags, say 400 feet. Most roads, however, use a variable length of curve depending upon the angle between the intersecting grades and the desirable gradation in change from one grade to the other. A rate of change of 0.2 per station on summits and 0.I per station in sags is very common and gives the necessary assurance against uncoupling of cars and breaking of draw bars. The A.R.E. and M.W. Association recommends that , "On first class lines a rate of change of 0.I per station on summits and 0.05 per station in sags should not be exceeded." and "On minor lines 0.2 per station on summits and 0.1 in sags may be used." Theoretically, the longer the curve the more nearly perfect will be the transition from one grade to another, but practically, it is a question whether the actual maintenance of such a curve will be consistent with the refinement used in establishing it.

The parabolic curve is the most commonly used from the fact that it is easily computed and affords the necessary transition. The principle of this curve is that the distances measured from the uniform grade, i.e., the ordinates, vary as the square of the distance measured from the beginning of the curve.

The familiar formula used for finding the length of the curve when the rate of change per station and the rates of the intersecting grades are known is: $L = \frac{g - g'}{2a}$ or $\frac{g - g'}{R}$.

L = length of curve in stations, symmetrical about the intersection of the two grades.

g = rate of grade(given in feet per station) of the initial grade line.

g' = rate of grade(given in feet per station) of the second grade line.

2a = R = specified change of curve per station in feet.

a = I/2 R and is the offset distnace from the grade line at the end of the first station from the beginning of the curve. It is analogous to the tangent offset at the end of the first I00 feet on a horizontal curve. R, the change per station, might be considered analogous to the degree of curve of a horizontal curve.

Grades can usually be laid so that the rate will be expressed in decimals of not more than one or two places, that is, in tenths or hundredths of one percent, and intersections can be placed at even stations, or plus fifties, without affecting the propriety or object of the grade line. They are not always laid, however, with ease of calculation of vertical curves in view. It is common to introduce rates of grade expressed by several decimal places due to necessary changes in bridge elevations, and in such cases vertical curves involving fractional stations, or intersections occuring at plusses, cannot be avoided.

Several methods may be employed for calculating vertical curves. Two convenient ones will be given.

Method I.a.- After the length of curve has been determined, elevations are calculated for each station along the initial grade line which may be assumed to extend to the E.C. of the curve. The proper increment, an^2, is then added to each elevation respectively just calculated to give the elevations for the corresponding stations on the curve. n = the number of stations from the P.C.

Method I.b.- Instead of extending the initial grade line to the E.C., the elevations may be calculated along both the initial grade line and the final grade line from the B.C. and E.C. respectively, toward the station of intersection, then the increments applied to each successive station beginning at the B.C. and E.C.

Method I.b. is usually better where the curve is long and there are elevations to be determined for various plusses, as might be the case where a trestle or bridge is on a vertical curve.

To facilitate the calculation of elevations at such places, or in fact for any points on any parabolic vertical curve, the following table P. 78 is given. The elevation for the given plus on the initial or final grade must first be calculated, then to this must be added (for sags) or subtracted (for summits) the offset given in the table for the distance from the B.C. or E.C. to the given plus. The offsets in the table are given for only every ten feet but intermediate distances may be easily interpolated to the nearest one hundredth of a foot which is as close as necessary. If Method I.b. is used the table will serve for curves 3000 feet in length.

The use of the table is illustrated by the following examples: To find the elevation of a fractional station at the end of a bridge.

Given: $g = -0.38\%$ $g' = +0.49\%$ $R = 0.1$

Station of intersection of grade lines	10 + 00
Elevation of " " " "	103.80
End of bridge ------------------------	8 + 37

$$L = \frac{-0.38 - (+0.49)}{0.1} = 8.7 \text{ stations.}$$

Station of B.C. = (10 + 00) - (4 + 35) = 5 + 65

Station of E.C. = (10 + 00) + (4 + 35) = 14 + 35

Distance of B.C. to end of bridge = 272 feet.

Elev. B.C. = 105.45.

Elev. on initial grade at end of bridge (Sta. 8 + 37) =	104.42.
From table, P. 78, the offset for 272 feet =	0.74
Elev. on vertical curve at end of bridge =	105.16

Two cases worked out by method I.b.

Case I. When it is desirable to set grade stakes every 50 feet or I00 feet from the B.C. or E.C. regardless of the plus.

Case II. When it is desirable to set stakes at every full station.

Example:

Given: g = -0.4 g' = +0.6 R = 0.I

Intersection of grades at station I0 + 38

Elevation of point of intersection I20.00

Then L = I0 stations.

B.C. = station 5 + 38

E.C. = " I5 + 38

Case I.

Station		Elev. on unif. grades	Dist. from end of curve	Offset from table	Elev. on curve.
5 + 38		I22.00	0	0.00	I22.00
6 + 38		I2I.60	I00	0.05	I2I.65
7 + 38		I2I.20	200	0.20	I2I.40
8 + 38		I20.80	300	0.45	I2I.25
9 + 38		I20.40	400	0.80	I2I.20
I0 + 38	Check	I20.00	500	I.25	I2I.25
I0 + 38		I20.00	500	I.25	I2I.25
II + 38		I20.60	400	0.80	I2I.40
I2 + 38		I2I.20	300	0.45	I2I.65
I3 + 38		I2I.80	200	0.20	I22.00
I4 + 38		I22.40	I00	0.05	I22.45
I5 + 38		I23.00	0	0	I23.00

Case II

5 + 38		I22.00	0	0	I22.00
6		I2I.75	62	0.02	I2I.77
7		I2I.35	I62	0.I3	I2I.48
8		I20.95	262	0.34	I2I.29
9		I20.55	362	0.65	I2I.20
I0		I20.I5	462	I.06	I2I.2I
I0	Check	II9.77	538	I.44	I2I.2I
II		I20.37	438	0.93	I2I.30
I2		I20.97	338	0.55	I2I.52
I3		I2I.57	238	0.27	I2I.84
I4		I22.I7	I38	0.08	I22.25
I5		I22.77	38	.00	I22.77
I5 + 38		I23.00	0	.00	I23.00

Method 2.- Where the B.C. and E.C. are at full stations or where it is sufficient to set stakes every 100 feet from the beginning, the following method is easily and rapidly applied.

Find the length of curve from the formula $L = \frac{g - g'}{R}$.

Find the station of the B.C. and its elevation.

We may think of the vertical curve as one which is changing its direction uniformly from B.C. to E.C. by a given rate R. It passes successively through all rates between g and g', that is, the curve is calculated by considering it a succession of grades or chords each 100 feet long and differing from the preceding or following one by the value R. The rate of grade for the first 100 feet differs from "g" by the value "a" and is therefore g - a, analogous to the deflection for the first 100 feet of a horizontal curve for which the value is one half the degree of curve or rate of change.

The rate of grade for the second 100 feet is g - a-R = g - 3a, for the third 100 feet g - 3a - R = g - 5a, etc.

The difference between g and a is always algebraic; the sign of "a" must be taken into account and is determined from the formula: $L = \frac{g - g'}{R}$, which transposed gives $R = 2a = \frac{g - g'}{L}$, or $a = \frac{g - g'}{2L}$.

Beginning with the elevation of B.C. the values g - 3a, g - a, g - 5a, etc. are applied successively and give the elevations of the curve for the respective stations at once.

This method may be used for shorter chord lengths but is rather involved and the "Method I" will serve better for such cases.

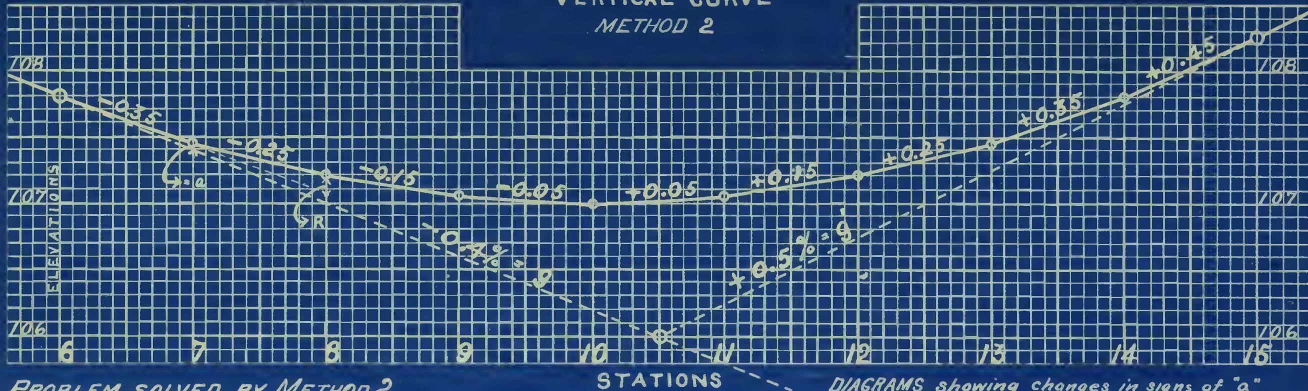
STAKES.- All work must be staked out before the contractor is allowed to begin grading. The stakes used in laying out excavation work should be of a good substantial character about 3/4X1 1/2X12"

VERTICAL CURVE OFFSETS
METHOD 1.

THE FOLLOWING TABLE GIVES THE OFFSETS (OR ORDINATES) TO BE ADDED TO, OR SUBTRACTED FROM, THE ELEVATIONS OF THE UNIFORM GRADE, FOR THE GIVEN DISTANCE FROM THE END OF THE CURVE, WHEN "a" = 0.1 OR R = 0.2. FOR OTHER VALUES OF "a" THE OFFSET IS DIRECTLY PROPORTIONAL, THAT IS, FOR "a" = 0.05 MULTIPLY THE TABULAR VALUE FOR THE GIVEN DISTANCE BY ONE HALF.

DISTANCE FROM B.C. OR E.C.	OFFSET	DISTANCE FROM B.C. OR E.C.	OFFSET	DISTANCE FROM B.C. OR E.C.	OFFSET	DISTANCE FROM B.C. OR E.C.	OFFSET	DISTANCE FROM B.C. OR E.C.	OFFSET
10	.001	310	.961	610	3.721	910	8.281	1210	14.641
20	.004	20	1.024	20	3.844	20	8.464	20	14.884
30	.009	30	1.089	30	3.969	30	8.649	30	15.129
40	.016	40	1.156	40	4.096	40	8.836	40	15.376
50	.025	50	1.225	50	4.225	50	9.025	50	15.625
60	.036	60	1.296	60	4.356	60	9.216	60	15.876
70	.049	70	1.369	70	4.489	70	9.409	70	16.129
80	.064	80	1.444	80	4.624	80	9.604	80	16.384
90	.081	90	1.521	90	4.761	90	9.801	90	16.641
100	.100	400	1.600	700	4.900	1000	10.000	1300	16.900
10	.121	10	1.681	10	5.041	10	10.201	10	17.161
20	.144	20	1.764	20	5.184	20	10.404	20	17.424
30	.169	30	1.849	30	5.329	30	10.609	30	17.689
40	.196	40	1.936	40	5.476	40	10.816	40	17.956
50	.225	50	2.025	50	5.625	50	11.025	50	18.225
60	.256	60	2.116	60	5.776	60	11.236	60	18.496
70	.289	70	2.209	70	5.929	70	11.449	70	18.769
80	.324	80	2.304	80	6.084	80	11.664	80	19.044
90	.361	90	2.401	90	6.241	90	11.881	90	19.321
200	.400	500	2.500	800	6.400	1100	12.100	1400	19.600
10	.441	10	2.601	10	6.561	10	12.321	10	19.881
20	.484	20	2.704	20	6.724	20	12.544	20	20.164
30	.529	30	2.809	30	6.889	30	12.769	30	20.449
40	.576	40	2.916	40	7.056	40	12.996	40	20.736
50	.625	50	3.025	50	7.225	50	13.225	50	21.025
60	.676	60	3.136	60	7.396	60	13.456	60	21.316
70	.729	70	3.249	70	7.569	70	13.689	70	21.609
80	.784	80	3.364	80	7.744	80	13.924	80	21.904
90	.841	90	3.481	90	7.921	90	14.161	90	22.201
300	.900	600	3.600	900	8.100	1200	14.400	1500	22.500

VERTICAL CURVE
METHOD 2



PROBLEM SOLVED BY METHOD 2.

GIVEN: $g = -0.4 \quad g' = +0.5 \quad R = 0.1 = 2a.$

STATION of P.I. = 10+50.

ELE. of P.I. = 106.00

L = Length of curve = $\dfrac{g-g'}{R}$ or $\dfrac{g-g'}{2a}$. $\quad a = \dfrac{-0.4-(+0.5)}{18} = -0.05.$

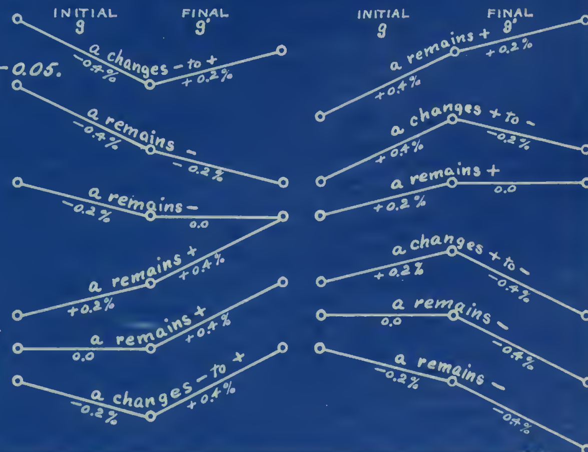
THEN, L = 9 stations.

Sta. of P.C. = 6+00, Ele. = 107.80.

Sta. of P.T. = 15+00, Ele. = 108.25.

STA. to STA.		GRADE	STA.	ELE.
6	7	$g - a = -0.4 - (-0.05) = -0.35\%$	6	107.80
7	8	$g - 3a = -0.4 - (-0.15) = -0.25$	7	107.45
8	9	$g - 5a = -0.4 - (-0.25) = -0.15$	8	107.20
9	10	$g - 7a = -0.4 - (-0.35) = -0.05$	9	107.05
10	11	$g - 9a = -0.4 - (-0.45) = +0.05$	10	107.00
11	12	$g - 11a = -0.4 - (-0.55) = +0.15$	11	107.05
12	13	$g - 13a = -0.4 - (-0.65) = +0.25$	12	107.20
13	14	$g - 15a = -0.4 - (-0.75) = +0.35$	13	107.45
14	15	$g - 17a = -0.4 - (-0.85) = +0.45$	14	107.80
			15	108.25

DIAGRAMS showing changes in signs of "a" for the possible relations between g and g'.



if sawed and planed, or larger if cut directly from the timber along the right of way. The station number should be placed upon the back of all stakes used for cuts, fills, and borrow pits, and berm stakes. It is a convenience also to have it upon surface ditch stakes, and wherever it is desirable to know the location of channels with reference to the center line. It takes less time to mark the stakes when they are set than to make extra measurements later to determine the plusses. On the front of the stake should appear the cut or fill plainly marked, preferably as shown in the sketch F2.3.

CUTS.- The cuts are staked out according to the standard road bed section of the railway. The cutting at the center of the road bed is marked upon the back of the station stake. The side stakes should mark the intersection of the slope of the cut with the normal ground. If the slope is properly trimmed it will exactly intersect subgrade at a distance one half the width of the road bed from the center line.

Where two or more materials having different slopes of repose occur in the same cut, stakes must be set for the flatter slopes first; then when the softer material is taken off, new stakes should be set for steeper slopes in the harder material. Most commonly the softer materials appear at the surface and the harder ones underneath, but the reverse may be true. In such a case the cut will be started too narrow and may have to be entirely re-cross sectioned unless the softer material can be kept back by shoring or by some other special treatment.

In rock cuts it is common to specify that the material shall be excavated from six to twelve inches below subgrade. The slope stakes are set without taking this into consideration. This extra

depth below subgrade is carried down with the slope used and the bottom of the excavation is, therefore, somewhat narrower than the road bed. It is later refilled with broken stone or ballast except at the sides where space is left for a ditch.

FILLS.- The work of staking out embankments is similar to that of staking out excavations. It should be kept in mind that earth embankments shrink and more material is necessary than the embankment section calls for. The practise of the road concerning shrinkage must be consulted before setting the stakes. Sometimes the side stakes are set out an additional specified distance on the assumption that the prismoid of earth must be increased at the sides as well as at the top to allow for shrinkage. It is more common practise to set the slope stakes for the actual section, then add a certain percentage in height only. It is also customary with some engineers to use different slope ratios, the assumption being that for high hills the base must be proportionately wider than for low ones, to support the excessive weight.

At the end of bridges it is usual to widen the road bed about two feet to give better support to the track, more room for piling bridge material, to allow for the sloughing off of the embankment due to working about the bridge, and to provide extra material for a run off from the bridge before the ballast is in place.

The heads of embankments at stream crossings should be wisely located, care being taken that the toe does not extend into the channel so far that it will be seriously affected by high water. The head of each bank should be staked out so that the distance between them will be about ten feet less than the distance from bulkhead to bulkhead. This allows for plenty of material back of

the bulkheads and prevents excessive settlement of the embankment at the end of the bridge.

A slope stake is set out on each side of the center line on line with the head of the bank, and one front toe stake on each line of the shoulder of the fill. These are usually all that are necessary. If the fill is high, an additional one may be set out diagonally on each side between the side stake and the toe stake. A cross section in this direction will assist in giving a more accurate determination of the volume in the head of the bank.

BORROW PITS.- Borrow pits may be located inside of the right of way between the slope stakes of the fill or cut and the property line, or they may be located entirely outside of the right of way. In the latter case, the material is purchased from the owner and due consideration must be given to the agreements made by the right of way agent with him. When the pit is located inside the right of way, careful attention should be given to the distance to be preserved between the slope stakes and the inside edge of the pit and the distance between the property line and the outside edge of the pit. It is often specified that the former distance shall be not less than 8 or 10 feet and the latter distance not less than 3 or 4 feet. The slopes should be 1 1/2 to 1 for earth. In some cases the slope near the property line is made 1 to 1. The tendency is always to make this latter slope vertical but this weakens the support for the fence and should not be permitted.

Borrow pits are most often made along the side of the fill and consequently on the lowest ground, probably near streams, where the most material is required. They are also farthest from the grade point of the cut, which shortens the haul of the material excavated from the cut. The fill is higher farthest from the grade

and the base wider, therefore the pit must be made narrow to keep inside the right of way. The dirt digs easily hear and the tendency is to dig a deep pit which will not drain properly. Whenever possible the pits should be excavated so as to drain well. The amount of borrow necessary to be taken from the pit cannot be estimated exactly so it will be impossible to stake the pit definitely and mark the exact cuttings on all stakes.

A grade line for the bottom should be assumed and the corresponding cutting marked upon the berm stake next to the road bed. The excavation should then be made as deep as the stake calls for at that point and the pit may be widened as much as necessary back toward the 3 foot berm near the fence line.

For convenience in measuring pits, always determine or assume a grade elevation for the bottom then read cuts or fills with respect to this grade. The notes will not have to be reduced afterward; besides, information concerning the reasonable or permissable depth of the pit is more easily comprehended on the spot.

Stakes should be set at every station with one at the 8 foot berm and another at the fence berm, each marked "berm" on the back; the former ~~else~~ should have the cut marked on the front, also if necessary to fix a grade line for drainage. The front of the stake is the side toward the excavation. The borrow pits should be cross sectioned when the road bed is cross sectioned, and, if the location of borrow pits is known at that time, the berm stakes may be set as the work proceeds and simply marked "berm". The cutting can be marked at some future time after the drainage has been investigated. They should be staked as regularly as possible with a view to their good appearance when finished, also with a view to accurate

measurements.

Where the work on adjacent stations is let to different men, the berm stakes may mark the limits of a contract. Each "station man" is doing perhaps only a station or two of work yet his little contract is just as important as a mile might be to the general contractor, and his limits should be just as carefully marked. For instance, the berm stakes may be "right angled" roughly and the outside stake be 5 or 6 feet from the perpendicular to the center line, yet make no appreciable difference in the distance out, and would make no difference in the total volume of excavation if one man had the whole contract; but if different men have the adjacent stations and the berm stakes have been lost then reset, perhaps on line this time, one man might get several percent of his contract more or less than he deserved.

CREEK DIVERSIONS.- If creeks are to be diverted from one channel to another and the diverting channel is excavated along the side of the road bed and inside of the right of way, it may be treated in the same manner as a borrow pit. If the ground is irregular, thus making the depth of the channel vary greatly from station to station, a uniform width of berm left next to the road bed will give a crooked line for the bottom of the channel. The better way is to run a straight center line for the channel then cross section it as an ordinary cut, taking care that at the widest part of the channel the slope stakes do not enroach upon the specified berm. Channels outside the right of way can always be staked much more satisfactorily from a center line.

Streams of considerable size and subject to floods should be carried through the road bed in their natural channels rather than

diverted along side the road bed to some other place of crossing.

SURFACE DITCHES.- Surface ditches are designed to protect cuts from water flowing in from the upper side which would tend to destroy the slopes and seriously affect the road bed. They should be placed not closer than IO feet from the slope of the cut, and the excavated material should be thrown up on the side next to the cut. The ditches should be at least one foot deep and three feet wide on top. Stakes should always be set for them. Better and more sightly ditches are made by shovels than by scrapers or graders, and the stakes will be better preserved by the former method. The tendency, however, is to do this work with teams and scrapers because it is cheaper. It is not the intention of the writer to discourage the cheapest reasonable method of doing work, but small pieces of work of this kind if done with teams will look exceedingly ragged, and are difficult to measure accurately. The ditches cannot be made less than three feet wide on bottom with scrapers. The contract price will usually cover the cost of doing these jobs by hand labor and no injustice will be done if this method is insisted upon. All surfaces ditches should be excavatedbefore the cuts are opened up.

Should it be unreasonable to attempt to measure accurately the borrow pit on account of unavoidable irregularities, such as boulders, classified material, etc., then it may be measured in the embankment with the necessary allowance made for shrinkage.

BERM DITCHES.- The surface ditches should be continued to the grade point and thence along the embankment, leaving the specified berm from which the the name of "berm ditch" originates. If borrow pits exist, the surface ditches will be carried into them. The

berm ditches are staked and measured as borrow pits.

ROAD CROSSINGS.- The maximum allowable grade is generally used at crossings to make the approaches as short as possible and thus decrease the amount of excavation. Ordinarily, however, where heavy loads are hauled along the highways the grade should not be greater than 5 per cent and the crown not less then 20 feet wide. The crown should be level adjacent to the track and even with the top of the rails. This level surface should be long enough on either side of the track to permit a team and wagon to stand upon it, so that a heavily loaded wagon approaching the track down the 5 per cent grade, as in a cut, can be stopped quickly; or should it be approaching up a 5 per cent grade, the heavy pulling of the team will cease before the track is reached, and the wagon and team will be wholly upon the level surface. To accomplish this the level grade should be extended 20 feet or more each side of the track.

As a basis for cross sectioning the approaches, a center line is run along the middle of the highway beginning at the center line of the railway as station zero, and extending each way. The highway is then cross sectioned along this line to the assumed grade and the usual stakes set.

Since the grading of these approaches must be done before track is laid, the summit of the approaches will be perhaps 12 or 18 inches above the crown of the railway road bed. Rather than leave the approaches unfinished until the track is laid, when it will be difficult to get graders to finish them, it is better to complete them at once and fill entirely across the road bed up to the permanent height, then let the track laying gang dig out a channel wide enough for the ballast and ties. Damage suits and the ill will of

the community are the usual fruits of the temporary expedients which are considered "good enough for a month or so" and which will barely permit a vehicle to pass over safely.

Private grade crossings are staked out similarly to highway crossings. The grade of the approaches may be steeper, perhaps IO per cent as a maximum, and the level surface at the track may be made somewhat less in length if the loads hauled over them are comparatively light.

The least amount of grading will be required if the crossing is located at a grade point, but the engineer is often compelled to locate it under direction of the property owner through the agreement made by the right of way agent. In most instances the company is bound to give each property owner at least one crossing.

Overhead crossings and subways are special problems, but in general, may be staked out from a center line beginning at the railway, and cross sectioned to the prescribed grade.

RAILROAD CROSSINGS.- The cross sectioning of the line at the grade crossing presents no new problems. The elevation of subgrade of the new road is usually determined by the elevation of subgrade of the existing line, and the thickness of ballast used on each.

In all of the work of staking out crossings of whatever kind the question of drainage must not be overlooked.

TUNNELS.- The important consideration in tunnel work is the accurate marking of the alinement and grade. The excavating gang will follow the specifications and plan for the bore and section. The engineer, however, must check them frequently.

The distance on the outside of the tunnel may be obtained accurately by triangulation. A method sometimes more feasible is to

drive hubs along the center line sufficiently close so that a tape may be stretched from one to the other, then the distance from hub to hub is measured, the elevation of each hub determined, and the horizontal distance calculated. The calculation consists in solving a right triangle for the horizontal side when the vertical side and hypotenuse are known.

Within the tunnel the center line may be carried by an offset line of plugs driven into holes drilled in the side of the tunnel, or by similar plugs driven into the roof on the exact center line. Small tacks or finish nails may be driven into the plugs for exact marks, or if the plugs are in the roof, small hooks may be used so that plumb bobs can be suspended.

Where the line must be carried down shafts extreme accuracy is required, first in fixing two points exactly on line at the top of the shaft which may not be more than eight or ten feet across, second, in transferring these two points vertically downward, and third, in establishing the line again from these two points in the tunnel. A conception of the required accuracy may be obtained from the following:

If two points are 8 feet apart and one is 1/32 of an inch out of line, about the width of the plumb bob string or wire, the angular error is slightly greater than one minute of arc, or 0.3 foot in 1000 feet.

At the top of the shaft two substantial and unyielding supports must be fixed to support a heavy plumb bob. The arms must project over the brink of the shaft far enough so that the plumb line will not touch any projections on the sides of the shaft and, therefore, they must be stiff to resist bending. A heavy plumb bob weighing

25 or 30 pounds is suspended by a fine wire from the points on line at the surface to transfer the line to the bottom of the shaft. To prevent excessive vibrations and oscillations, the plumb bob is made to hang in a vessel of water or oil. A barrel of water is sometimes used to advantage. Care must be observed in "lining in" the suspending wires themselves, rather than the hooks or supports to which they are attached at the top of the shaft. At the bottom of the shaft several observations should be made upon the wire with the transit to be sure the wires are truly vertical and not oscillating when sighted upon. Frequently the shafts are sunk to one side of the tunnel so when the center line is carried down from above as an offset line it must be transferred again as an offset into the tunnel. The necessity of extremely careful work is emphasized by the fact that offsets must be made above and below and that the line is lowered by at least three delicate operations performed upon a section of the center line only a few feet in length!

PILE BRIDGES.- Pile bridges are often staked out by placing a single stake exactly at the point where the pile is to be driven. By marking the point in this way there is little chance for error, since the pile driver can be set precisely over the point. Occasionally the stakes are set the proper distance from the center line but perhaps one foot in fron of, or back of, the point where the pile is to be driven. The contractor must then measure this distance of one foot to locate the pile. This is not good practise since the engineer should himself fix the final position of every stake. Another objection to setting the stakes in this way is that when the pile is being driven it crowds the stake aside, particularly in soft ground, so that it no longer represents the distance intended. This

is true more or less with the stakes however they are set, but if there is danger of their being very much dispalced the better way of overcoming the difficulty is to set a stake on each side of the bent and on line with it, and sufficiently far from the center line so that the stakes will not be disturbed. These stakes will serve not only to fix the line of the piles normal to the center line, but will also fix points from which to measure to check up the proper location of every pile in the bent. If the bridge is long, these side reference stakes may be more quickly set by running them in as offset lines a convenient distance from the center line, unless the trestle is on a curve, in which case it will usually be better to set the center stake for each bent, then turn normals with the transit every two or three bents, depending upon the degree of the curve, and measure or estimate radial lines for the intermediate bents.

If the trestle is low and the width of the bents at the ground, therefore, narrow, right angles or normals may be established by measuring with the chain or tape. (See methods of laying off and measuring angles with tape.)

The trestle plan must be consulted and carefully observed. The two end spans will usually be about half the diameter of a pile shorter than the other spans, from the fact that the stringers must extend to the outside of the cap on the end bent instead of to the center of the cap. Sometimes about two inches allowance is made for fitting the stringers. A span that is called a I5 foot span may be staked out only I4 feet, IO inches, in length.

Elevations should be taken upon the ground where each pile is to be driven so that the penetration may be calculated, or at least

checked.

Some good reference points should be established between the ends of the bridge if it is long, or on a curve, or the ground is badly broken, since after a few bents are erected all back sights or foresights may be obscured.

FRAME TRESTLES.- For locating framed trestle bents the method of placing two stakes on a line normal to the center line to mark the center of the bents, as suggested above for pile trestles, is common, and perhaps the one usually followed. These two stakes set at known distances each side of the center line may suffice if the ground is level and sufficiently hard for a good foundation.

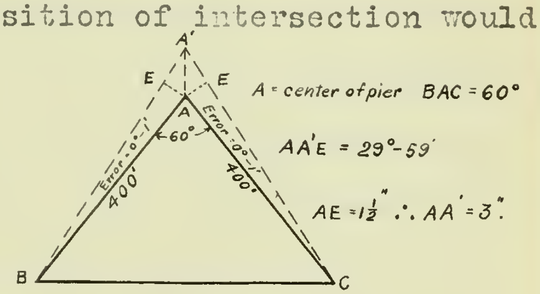
If on side hills or broken ground and considerable excavating must be done to level the sills, stakes should be set to mark the limits of excavation for the mud blocks, and also to be used for reference when measuring up the excavation for estimates. The stakes can be marked most intelligently by the engineer while he has his level at the site.

VIADUCTS.- The center line must be checked, then transverse lines run out with the transit on the line connecting the center of the pedestals. The latter are then located in the most practical way, consideration being given to the unevenness of the ground, the depth of excavation necessary, and accessibility to reference points. Offset transverse lines parallel to the lines through the center of the pedestals will be most convenient for instrument work, but extreme care must be taken not to confuse them with the actual transverse center lines through the pedestals.

Elevations should be taken from which to calculate excavation quantities. Span bridges will be staked out similarly to viaducts

if supported on towers or pedestals, otherwise the piers or abutments supporting them will determine their location.

PIERS.- Piers are located usually by measuring with long steel tapes from the shore, if the distance is not too great, and ranging in the lines with a transit. If the distance from shore is great and chaining is not practicable, then they should be located by triangulation; care must be taken in triangulating to get well proportioned triangles. Those approaching equilateral triangles are the best. The exact center of the pier may be located, or a line of given length passing through the axis of the pier. The line is preferable as it fixes the position and the orientation of the pier at once. Extremely accurate work is necessary, and frequent checks should be applied. An error of one minute of arc amounts to a deviation of 35/100 inch or about 3/8 inch from the true line for every 100 feet in length. If two lines are 400 feet long and an error of one minute is made in each in opposite directions and the angle of intersection is 60° the error in position of intersection would be about 3 inches. See Figure.



ABUTMENTS.- Abutments are usually set upon a footing course of masonry or concrete which projects six inches or more all around the abutment. Stakes must be set for the outside limits for the footing first. These stakes should be set carefully but exact points need not be marked upon them unless it is desired that the limits of footing be true to line. If deep foundations are to be laid, it may be necessary to allow several inches outside the prescribed footing for shoring to keep the earth and other material from coming in. If investigation shows that the

foundation is uncertain, the excavation for footing may be approximately staked, then when the footing is built up to the proper elevation the neat lines of the abutment at the top of the footing may be staked out. If the neat lines are staked before the excavation is made the stakes are likely to be covered up or disturbed by the workmen.

The exact plusses of the front and back of the abutment should be calculated and located on the center line to the 0.01 foot or 1/8 inch. All angles between lines over 10 feet long should be turned off with a transit. All possible check measurements should be made in laying out bridge and masonry work. Errors creep in in the following ways: reading tenths for inches, using a tape with only every 5 feet marked with a numeral, reading 6 for 9 or 9 for 6 when the tape is wrong end ahead, reading the "big" end of the tape and subtracting, allowing a rodman to read the tape instead of giving him the zero end, etc.

The stakes should be so placed that when a string is stretched between the proper points it will determine the neat lines and give all intersections at corners. Hubs may be set flush with the ground and tacks used to mark the points, then guard stakes placed behind them; or if not likely to be disturbed, substantial stakes may be set to project several inches above the ground and nails driven in the top upon which a builder may stretch his string at once. A large number of stakes is often necessary so they must be very carefully marked. It is always desirable that the engineer be on the spot to direct the contractor in laying out the neat lines upon the footing. Bridge work should fit to a nicety and the engineer should never feel ~~too~~ confident that his work is staked out

accurately until he has checked it several times, and by different methods.

Ground elevations should always be taken at the footing stakes to aid in computing the foundation excavation.

RETAINING WALLS.- Retainingwall footings are first staked closely approximate, then, when the footing courses are built up to their proper height, the neat lines, i.e., lines of intersection of the faces of the wall with the footing, are located so as to bring the top or coping to the desired line when the wall is built to the required height. An offset line is convenient and often necessary for resetting footing or neat line stakes should they be disturbed during the process of the work. As the wall is built up, the view along the line is obscured and stakes can be reset only from the offset line. This is also true if the base of the wall is curved. The offset line should be located with reference to some unvarying line of the wall such as the front of the wall at the top under the coping, or the front of the coping if the top of the wall is a level line.

Ground elevations must be taken at the footing stakes before any excavation is made.

CULVERTS.- Culverts should be located with a view to obtaining a firm foundation to prevent settling when the weight of the embankment comes upon them. It is often better to locate the culvert several feet from the old channel even though the amount of excavation is large than to locate it in a yielding or water soaked foundation. Consideration must be given to the line of the channel leading to the entrance, and from the exit, of the culvert. It should not be tortuous or acute angled so as to cause eddies or collect

debris which would clog the waterway, nor should the channel be changed so as to discharge upon property that might be damaged thereby.

The slope or grade to be given to a culvert is usually determined by the normal slope of the ground. If the slope of the ground is steep it may be wise to shift the culvert to obtain less slope and thus prevent excessive scouring of the paving or undermining of the culvert by a swift current. The same result may be accomplished by lowering the upper end of the culvert, but unless the slope of the approach to the culvert can be made gentle, the lowering of the upper end of the culvert will cause a deep hole to be scoured out at the entrance. The lower end of the culvert should not be raised above the ground level so that a waterfall will be formed unless the place of discharge can be well rip-rapped. Even then it is not advisable.

There should always be sufficient slope, not less than 0.5 per cent, given to the culvert so that it will drain well. No maximum limit of grade can be given since the design of culverts varies greatly. A culvert with no head walls and open paving, or no paving, would not permit of a steep grade, while one with wide and deep head walls, with a concrete paving, or deep cross walls, might permit of almost any practical grade without danger. Grades as steep as four or five per cent are sometimes used.

It is sufficient to state that for masonry culverts the stakes are set practically in the same way as for abutments, that is, the stakes should be so set that lines stretched from one to the other will intersect at the limits of all neat lines.

Skew culverts should be avoided. Wherever possible culverts

should bestaked out at right angles to the center line of the road. The angle should be turned with a transit, particularly for long culverts. It is always a good plan to set a hub at each side of the right of way on the center line of the culvert at a known distance out for reference in checking up, or resetting, excavation and neat line stakes.

For pipe culverts a line of stakes along the center line of the culvert is usually all that is necessary, one stake marking the end of each joint of pipe. The stakes indicating the excavation for the proper grade line are first set and marked with the proper cut, then after the excavation is about finished, grade stakes should be set at the end of each joint.

A camber is often given to pipe culverts so they will not become dished at the center. It is easily accomplished by making the grade of the culvert parabolic in form, convex upward.

Example~~s~~.- If the culvert is composed of four I2-foot lengths, the elevation of the upper end is I02.00 feet and the elevation of the lower end is I00.40 feet, then the difference (I.6 feet) divided by $(4)^2$, gives 0.I foot as the offset to be subtracted from the elevation I02.00 to give the elevation at the lower end of the first joint. The succeeding offsets vary as the square of the distance from the upper end of the culvert and are therefore .4 for the lower end of the second joint and .9 for the lower end of the third joint.

The abscissa of the parabola may be either a level, or a sloping, grade line. In the example given it is a level grade line.

The length of the culvert depends upon the design chosen. If head walls are used the formula L = b/2 + SH may be used, where L=

length of center line to back of head wall, b = width of road bed, S = slope of embankment= I I/2:I for earth, and H = difference in elevation of subgrade and top of head wall. If no head walls are used H = difference in elevation of subgrade and top of culvert. The culvert should then project a foot or two farther, or L = b/2 + SH + 2 feet. The formula must be applied to each end of the culvert separately since there may be a considerable difference in elevation of the two ends of the culvert due to its grade.

When more than one row of pipes is used the center lines of the rows should be sufficiently far apart to give a clearance of not less than three feet to permit of a thorough tamping of the filling material underneath the sides of the pipes.

CHAPTER VIII

MEASURING UP THE WORK

The work done upon the residency is measured up by the resident engineer and from his figures the contractor is paid. Measurements are made at intervals as the work proceeds, usually every month, and also upon completion of the work. The monthly estimate is only approximate but the final estimate should be carefully made and as nearly accurate as possible. It is the writer's opinion that monthly estimates should be made closely approximate, so that if the contractor is deserving of a close estimate he will get pay for practically all that he has done, so far as the measurements will give it to him. There is always a percentage retained, varying from 5 to I5 percent which may amount to considerable on a large piece of work, and that, in most cases, is penalty enough.

All work should be measured up carefully for a final estimate as soon as it is completed whether it has been accepted or not. Particularly is this true of grading where a delay may result in difficulty in obtaining exact measurements on account of washes, slides, silting, etc.

CLEARING.- Clearing may be paid for by the acre or by the "square" of I0,000 square feet, the latter being based upon one station length of right of way I00 feet wide. If the clearing is completed according to specifications then only the length of the cleared portion need be measured. Completed work implies that the brush and unusable logs shall have been burned, the usable logs

properly piled, and all objectional branches overhanging the right of way from trees outside, removed. In heavily timbered country an extra price is given for skidding or piling the logs, usually a certain price per 1000 feet log measure. This necessitates measuring up all the usuable logs. They are measured with a lumberman's log scale which gives the feet board measure for any ordinary sized log. The length of the log must be measured in feet with a tape or rod, and the small diameter under the bark measured with the log scale. On the scale opposite the diameter in inches, and for the given length in feet, the feet B.M. is read off.

Where there are isolated trees along the right of way the cost of clearing may be estimated at so much per tree, or on the acreage basis by measuring the over hang of the branches, i.e., the horizontal projection of the tree, or by mutual agreement of a definite number of trees of a specified size per acre.

Trees are sometimes reserved by the company and cut up into ties and cord wood. The ties are hewed and neatly piled, the labor being paid for at a certain price per tie. The labor of cutting and piling cord wood is paid for by the ~~h~~cord of 128 cubic feet. This labor includes burning the brush and other waste.

GRUBBING.- Grubbing is usually measured in units of a square rod or square station, preferably the latter. Unless otherwise specified, all cuts that must be cleared will be measured for grubbing, the area being taken between slope stakes. Grubbing must be done under all fills of a specified height, usually two or three feet, and sometimes upon the berm, or for a certain distance (6 to 10 ft) outside of the slope stakes of embankments. Borrow pits must also be grubbed. The areas are nearly always obtained by measuring along the center

line of the road for one dimension, that is, station to station, the other dimensions being determined by the slope stakes, borrow pit stakes or berm stakes.

EARTHWORK

CLASSIFICATION.- The classifying of materials excavated is one of the most perplexing duties that the resident engineer has to perform. Specifications are often vaguely worded, but even though they were perfectly worded it would still be difficult to make the classifications on account of the almost infinite range in the kinds encountered. There are all possible gradations from the softest earth to the hardest rock. No two engineers may agree upon any one material as coming under the same specifications. A good illustration of this point is found in the numerous ways in which specifications for classification are written by the various railroads. This subject is discussed very interestingly in the Proceedings of the American Society of Civil Engineers, Vol. 58-1907.

CUTS.- For monthly estimates as well as for final estimates the centerline should be re-established in the cut. The plusses are thus closely measured, and the transverse distances not only give the width of the excavation but check the symmetry of the work. It is customary and fair to give no estimate on material excavated outside of the prismoids as staked. If the width of the bottom of the excavation is measured regardless of the centerline it is difficult to dtermine whether the excavated section coincides with the prismoid staked or not.

It is sufficiently close for monthly estimates to take one representative elevation at the centerline at each section, except perhaps in very large earth cuts, or in rock work and other class-

ified materials. In these latter it is well to have sufficient data as the work proceeds so that the progress cross section may be plotted. Such data may be difficult to obtain later.

For final estimates the center line must be re-run and the widths at the top as well as at the bottom of the cut must be measured for a check on the prismoid. If the prismoid is perfectly excavated the total quantity is allowed. The cut ditches are then measured separately. If uniformly excavated as per the standard plan, the ditches need only be checked for cross section and measured as so many stations long.

In rock cuts the sub-grade material must be excavated before the full section is allowed.

BORROW PITS.- Borrow pits are measued most accurately by taking cross sections at the stations and plusses where originally cross sectioned. If the pits are narrow and quite uniform in section they may be measured more rapidly and with sufficient accuracy for monthly estimates by holding the zero end of the tape at one edge of the pit, stretching it tightly across to the opposite edge, then with a graduated rod measuring the depth of the bottom of the pit below the tape at the necessary points, recording the distance of these points out from the zero edge. This method assumes that the original ground had a uniform slope from edge to edge of pit and that no accumulations, or erosions of the natural ground, have taken place along the pit where the tape is held. The length of the borrow pits are recorded in stations and plusses. Where the pits are wide and irregular and recorded with reference to the center line this method should not be used.

Where borrow pits have been excavated outside the right of way

and the area was cross sectioned by running range lines across and taking elevations at their intersections, these lines should be re-run and elevations taken at the same points. They can be ranged in sufficiently close by eye if permanent points have been established at the limits of the pit.

Material excavated from borrow pits, in general, is not classified, being paid for at the minimum price. Only in special cases is over-haul allowed on borrowed material.

TUNNELS.- In tunnel measurement the section called for by the standard plan is allowed, providing the excavation checks with this section. The specified clearance must be had in every direction. Classification is not generally considered since there is a special price for tunnel excavation covering whatever material is found.

DITCHES.- Ditches, if large, should be cross sectioned with the level, but if small, such as berm ditches and surface ditches, they may be measured in section by tape and rod as indicated for narrow borrow pits, the length being measured along the center line of the ditch.

OVERBREAK.- There are often instances in heavy rock where the material is of a different nature, and the strata have a different dip, than was anticipated, and it is impossible to excavate the section to the slope as determined by the slope stakes. The blasting may unavoidably loosen material outside of the prismoid, which if allowed to remain would endanger the track. Such material should be removed and it is just that the contractor be paid for handling it. The engineer should satisfy himself, however, that such over-breaks are not caused maliciously, or by the excessive or unwise use of explosives; and, although it is well to measure it, he should

never turn in an estimate on "overbreak" without the approval of the chief engineer.

SHRINKAGE AND SWELL.- Shrinkage and swell do not enter into the measurement of pay quantities unless there is a"two way" price on the material. The "one way" method, that is paying for the material in excavation only, is the most common one and is, without doubt, most fair and reasonable.

WET EXCAVATION.- Wet excavation is treated as a special case and if not defined clearly in the specifications, the chief engineer should be consulted before it is estimated. It is measured in connection with foundation for piers, abutments, retaining walls and culverts.

OVERHAUL.- This subject is treated under the head of Calculating Quantities.

The measurement of the amount hauled is included in excavation measurement. The distance hauled is determined by noting between what stations the embankment has been built. The height of embankment is determined by taking elevations along the centerline on the top.

BRIDGEWORK

TRESTLES.- The monthly estimates on trestle work are practically final so far as they go and, therefore should be measured with the accuracy of a final estimate.

Pile.- The field measurements forestimating the work done on a pile trestle consists chiefly of getting the number of piles driven, their length, penetration and cut off, and the lineal feet of deck that has been completed. Most, if not all, of this information may be obtained from the pile recorder's book. The piles should be meas-

ured to the nearest I/IO foot.

The "cut off" elevation for piling is determined by calculating the distance from base of rail since all the trestle elevations are referred to the base of the rail grade line. The "cut off" referred to elevation of sub-grade is obtained as indicated in the figure on page . The following formula also gives the method of calculating it:

Elevation of cut off = elevation of sub-grade + thickness of ballast under tie + thickness of track tie - (thickness of tie plate + thickness of bridge tie + depth of stringer + thickness of cap). All iron is paid for separately.*

*It should be checked to see that all that is required by the standard plan is provided.

Frame.- In the monthly estimates the number of bents in place are counted and measured, together with the completed part of the deck. Only the length of completed deck need be determined. If the trestle is paid for on the basis of the actual amount of timber entering the structure, rather than on the bill of material as given in the preliminary estimate, then the exact height of all vertical posts should be measured to the nearest 0.05 foot, or half inch. The engineer can usually get this information from the bridge book which contains a record of the elevations of the sills, but it sometimes happens that changes are necessary during the course of the work, and the elevations and dimensions should all be checked before the estimate is calculated.

Mud blocks that have been permanently placed may be included in the monthly estimate, but it is not always well to do so on account of possible changes which prevent their being considered finished

work.

MASONRY.- Piers, abutments, retaining walls and culverts of stone masonry or concrete are built according to plan and it is only necessary for the engineer to check up carefully the dimensions of the complete structures as called for upon the plans. For the footing or foundation of these structures, however, the actual field measurements serve as the basis of the estimate since it cannot be specified upon a plan how deep the foundation shall be dug or what shape it shall assume.

Measurements should be made with steel tape on all masonry work to 0.05 foot on foundations, and 0.0I foot on the parts above the footing.

For monthly estimates measurements of piers and abutments where the sections are not completed, the height is obtained by taking enough measurements to give a fair average. For culverts and retaining walls, the heights of uncompleted sections and length of completed sections are measured.

The level is most reliable for measuring heights, especially where the structures have battered sides.

The measurements should be sufficiently close to give results to the nearest cubic yard on culverts or pieces of work of I00 cubic yards or less, and to the nearest five cubic yards on structures of greater magnitude.

CULVERTS.- Paving for culverts, and rip rap or dry walls, should not be overlooked at estimate time. These items, though of less importance than the masonry structures, should be carefully measured on account of the irregular shapes which theytake.

Paving of a specified depth may be measured on the basis of

square yards of surface instead of on the basis of cubic yards.

Headwalls of culverts if built according to plan need only be checked for dimensions.

Wooden culverts are paid for by the 1000 feet board measure, and and are therefore measured as trestle timber. Cross walls, or apron walls, of timber are often used to prevent scour, and to tie the culvert properly, and should be taken into account in the estimate. They should be inspected and measured when laid, as should also the side walls. If hewn timber is used it may be dressed on only three sides but the bark should always be removed, and the bearing or hewn surfaces made at least as wide as the plan calls for.

Drift bolts, spikes and dowels must also be taken into consideration.

Iron pipe is very commonly used for culverts where stone masonry or concrete is expensive or difficult to obtain. The usual sizes range from 12 to 60 inches in diameter by 12 feet in length. Those of large diameter are sometimes made in 6 foot lengths. The labor of placing them is sometimes paid for by force account, or by weight at a certain price per ton.

They may be built either with or without headwalls. Where headwalls are used they will be measured up as masonry in the ordinary manner.

Cribs, cofferdams, sheet piling, arch, and tunnel centers, concrete forms, temporary trestles, etc., are usually accessories to other work and are paid for in the unit price for that work. If it is specified that they shall be paid for separately, they will in general be built to some plan furnished by the engineer and this will guide in their measurements. All such structures are best

checked and measured up by the engineer or the inspector as the work proceeds, as it is often difficult to estimate if left till the end of the month or until the worl is completed.

Haul of materials.- See Calculation of Haul.

CHAPTER IX

CALCULATING THE QUANTITIES

The last few days of each month is a strenuous time for the resident engineer. The contractor is always glad to have his work measured up on the last day of the month so he will get the largest possible estimate; and the chief engineer's office force is equally well pleased to have the estimate in the office on the first day of the following month. It is hoped that the suggestions and tables given in the following pages will aid the resident engineer in makeing calculations for estimates and relieve him of some of the tension of the estimate season.

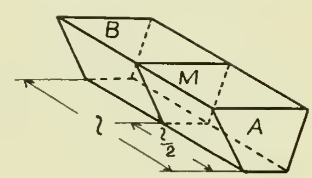
EARTHWORK

EXCAVATION.-All sections should be plotted to scale. This may take considerable time but it gives a good idea of the form of the section and hence assists in the calculation. The cross ruling of the paper gives an approximate check upon the area. If a planimeter is at hand, a close check may be obtained. Plotted sections are of greatest value in showing classification and progress of work, and in calculating irregular sections.

Two methods are commonly used in the calculating of earthwork, the Prismoidal method and the Average End Area method. In prismoids where the bounding surfaces can be measured accurately, the quantity can be computed accurately by the prismoidal method. This is not true of the end area method if the ends are unequal in area, the results being greater than the actual volume. The difference in re-

sults obtained by the two methods is small, however, when the end areas or center heights are not widely different.

Some engineers specify the End Area method for approximate or monthly estimates and the Prismoidal for final estimates. Others, and perhaps the majority, consider the End Area method consistently accurate for all estimates. Elevations are taken on the ground to tenths of a foot and slopes are never exactly uniform from one cross section to the next. If the Prismoidal formula is used either a center height must be interpolated midway between the end sections, or an additional mid-section must be taken in the field. If an additional section is taken in the field to be used as a mid-section in the Prismoidal formula, it might just as well be used as the end area for a shorter section and the volume computed by the End Area method. For if the center heights of two adjacent cross sections vary greatly the intermediate ground slope is not likely to be uniform except between sections close together. If sections are taken close together so that the difference in center heights will be small, then the difference in volumes obtained by the two methods is small.



The Prismoidal formula is: $V = l/6(A + 4M + B)$

V = volume in cubic feet.

l = length of prismoid, or distance between end sections, in feet.

A and B are areas of the respective end sections in square feet.

M = area of the middle section in square feet.

It must be remembered that M is the area as actually measured or calculated midway between A and B and not the average of A and B This is shown in the following simple problem:

At A, Bottom width=6, top width=10, center height=8, area=64.

At B, Bottom width=8, top width=12, center height=10, area=100

M " " =7, " " =11, " " = 9, " = 81

The average of A and B gives an area of------------------- 82

PRISMOIDAL CORRECTION.- If it is required that the theoretical accuracy of the Prismoidal Formula be secured, the calculation may be somewhat simplified by applying the prismoidal correction to the results obtained by the Average End method. This correction need only be applied when the difference between center heights at the two ends of the prismoid is greater than three feet.

The Prismoidal Correction for prismoids having a uniform width of base, as a roadbed section, is $C = \frac{l}{12}(C_0 - C_1)(D_0 - D_1)$, or in words, "The correction in cubic feet to be subtracted from the volume obtained from the Average End Area method is equal to 1/12 of the length of the section, times the difference in center heights of the two ends, times the difference of the sum of the distances out from the center at the respective ends."

The accompanying table is worked out from this formula and gives difference of center geights up to 10 feet, and difference of distance between slope stakes at the two ends up to 30 feet.

The length assumed is one station (100 feet) and volumes are in cubic yards. For fractional feet interpolation is made directly.

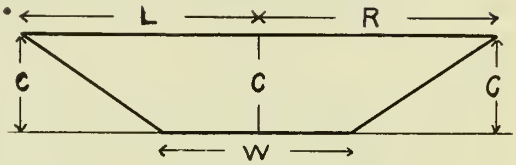
END AREAS.- The following methods are the most common for use in calculating end areas of sections:

(1). Irregular Section.- For irregular sections the cross section must be divided up into its simplest figures, either triangles or trapezoids, and these calculated separately, then added to give the total area. The irregular sections are often laborious to compute, but there is no short cut method that can be applied. For such

sections having a great number of heights, Simpson's I/3 Rule might be used, though its advantage is questioned. See page .

(2) Level Section.- For a level section the formula is:

A = C/2(W/2 + L or R), or A = C(W + SC).



(3) Three Level Section.- There are two rapid methods of calculating the area of a Three Level Section. They can best be explained by the following figures.

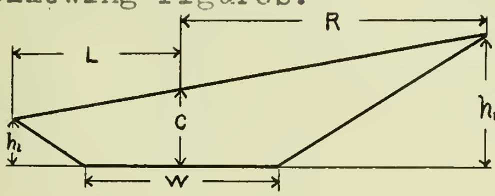


Fig. a.

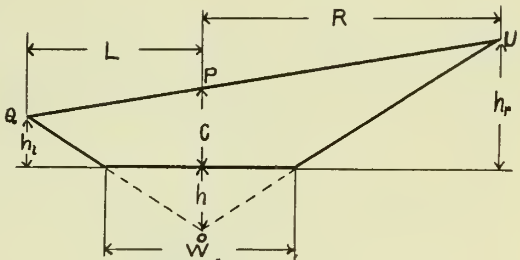


Fig. b.

a.- Let c = center height, h_l = height on left, h_r = height on right, L = distance out on left, R = distance out on the right, W = width of the roadbed.

From Fig. 1 the area A = four triangles, c is the common base of two, and W = the base of the other two.

$A = h_l W/4 + h_r W/4 + Lc/2 + Rc/2 = (h_l + h_r)W/4 + (L + R)c/2$, or in words: The area equals the sum of the side heights times one fourth the width of the roadbed plus the sum of the distances out times one half the center height.

b.- From Fig. 2 we consider the slopes extended downward to an intersection forming a triangle having the width of the roadbed, w, for its base, and known as the Grade Triangle.

s = slope = horizontal distance divided by vertical distance, h = height of grade triangle, h = W/2s, Area of triangle = W/2s x W/2 = $W^2/4s$, a constant for any given road bed and slope.

Area of large triangle OPU = $(c + h)R/2$ = $(c + W/2s)R/2$.

" " " " OPQ = $(c + W/2s)L/2$.

" " OPQU = $(c + W/2s)R/2 + (c + W/2s)L/2 = \frac{L + R}{2}(c + W/2s)$.

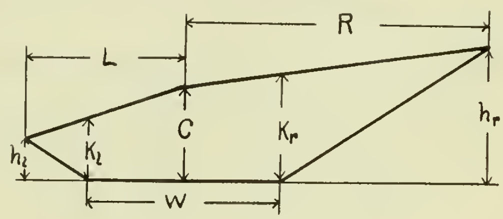
Subtracting the grade triangle gives the area of the roadbed section = $A = \frac{L + R}{2}(c + W/2s) - W^2/4s$.

Expressed in words: Subtract the area of the grade triangle (the square of the width divided by four times the slope) from one half the sum of the side heights multiplied by the sum of the center height, and the width of the roadbed divided by twice the slope.

At the end of the chapter is a table based upon this formula and intended to shorten the work of calculating regular Three Level sections.

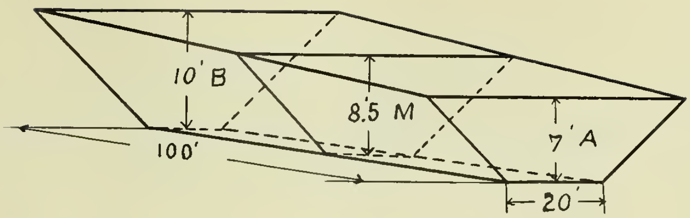
(4). Five Level Section.- For a Five Level Section, that is, a Three Level section with two additional heights, k_l and k_r, one over each edge of the roadbed, we have the following formula:

Area = $\frac{CW + Rk_r + Lk_l}{2}$.



In words: The area is equal to one half the sum of the center height times the roadbed, the distance to the left slope multiplied by the intermediate height on the left, and the distance to the right slope multiplied by the intermediate height on the right.

PROBLEM COMPARING METHODS.- The following problem will show the application of the Prismoidal Formula; also the difference in volumes as obtained by working out an ordinary sized prismoid by the Prismoidal Formula and Average End Area methods respectively. The application of the Prismoidal Correction to the same prismoid is also given.



Given:

Two level cross sections A and B.

$w = 20$ feet. $S = 1\ 1/2$ to 1. $l = 100$, distance A to B

$C_A = 7$ feet, $C_B = 10$ feet.

Then $C_M = 8.5$ feet, $A = 213.5$, $B = 350.0$, $M = 278.4$-

Volume by Prismoidal Formula $= V_P = 100/6(213.5 + 4x278.4 + 350.0)$

= -- 27950 c.f.

Volume by Av. End Areas $= V_E = 100\dfrac{213.5 + 350.0}{2} =$ 28175 " "

Correction to be subtracted from Av. End Area = 225 c.f.

Prismoidal Correction $= C_P = l/12(C_B - C_A)(D_B - D_A)$

$= 100/12(10 - 7)(50 - 41) = 225$ c.f.

$= 8\ 1/3$ cu.yd

The consistent accuracy of the methods given above is illustrated as follows: Suppose the level rod gave a reading 0.1 foot too small; then C_A, as recorded, = 6.9, and C_B, as recorded, = 9.9. The error in volume is then $\dfrac{40.85 + 49.85}{2}100 = 453.5$ cu. ft. = 16.8 cu. yds.- about twice the difference of the results obtained above, that is, twice the Prismoidal Correction. Assuming that each rod reading is correct to the nearest 0.05 foot when reading to 0.1 foot, the error due to the reading of the rod would just equal the Prismoidal Correction. Therefore, for a difference in center heights of three feet or less between cross sections 100 feet apart there is practically no advantage, even in accuracy, of the Prismoidal Formula over the Average End Area method.

Curvature Correction.- Where the curvature is considerable and

the cuts and fills are large, a correction for curvature may be necessary. This is added when the greatest side height of the cross section is on the outside of the curve, and subtracted when ~~when~~ the greatest side height is on the inside of the curve. When the side heights of the same section are equal, that is, the cross section is symmetrical, there is no correction. The error is due to the assumption, in calculating, that the end areas are at right angles to the chords of the curves in the ordinary unsymmetrical section.

The correction formula is $C_c = (w/2 + SC)\frac{hr - hl}{2} \times 2/3(\frac{R + L}{2})x$ angle (arc measure) between the chords of the two adjacent prismoids.

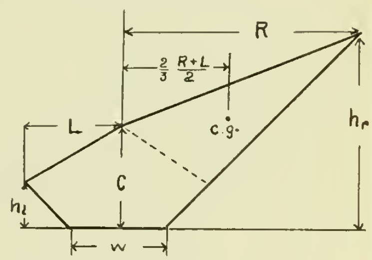
$(w/2 + SC)\frac{hr - hl}{2}$ is the area of the unsymmetrical excess part of section.

$2/3(\frac{R + L}{2})$ is the distance of the center of gravity of the excess area from the center of the cross section.

The angle between the chords (or end sections) is equal to the degree of durve, D, when the adjacent chords are each 100 feet long. For shorter chprds the angle is $D' = \frac{\text{Sum of adjacent chords}}{200}D$.

Curvature Correction Problems.-

Problem 1.



Given: The section, $\frac{+10.0}{25.0} + 16.0 + \frac{40.0}{70.0}$
Sections are 100 feet apart, that is, the angle between chords is equal to the degree of curve.

Then applying the Curvature Correction formula,

$C_c = (\frac{20}{2} + \frac{3}{2}16)(\frac{40 - 10}{2})\frac{3}{2}(\frac{25 + 70}{2})(0.01745 \times 10°) = 2820$ cu. ft. =104.4 cy.

The area of the section shown in the figure is 1010 sq. ft. and a prismoid 100 feet long having an average section of this area

will contain 3740.7 cu. yds. The error due to neglecting the Curvature Correction of 104.4 cu. yds. is therefore about 2.8%, an amount too large to be neglected. The example given is an extreme case but a possible one. It might occur on side hill work in a mountainous country where the sections are very likely to be unsymmetrical and the curves sharp. The error, due to neglecting this correction would favor the contractor, ~~and~~ since the road follows the contours, and the excess area of the cross section would in most instances be found on the inside of the curve. The Curvature Correction would therefore be negative.

Prob. 2.-

For a more usual section take $\frac{+8.0}{22.0}$ $\frac{+10.0}{0}$ + $\frac{12.0}{28.0}$ on a 4° curve.

The area of the section = 350 sq. ft., the volume per sta.=1296.3

Cur. Cor. = $(\frac{20}{2} + 15)(\frac{12 - 8}{2}) \times \frac{2}{3}(\frac{28 + 22}{2}) \times 0.01745 \times 4 = 58.2$ cu. ft. = 2.2 cu. yds.

The error here is 2.2 cu. yds. or 0.17 of 1% which is much less than the probable error due to reading the rod only to the nearest 0.1 of a foot.

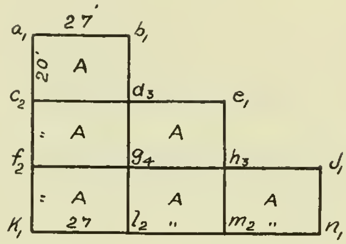
From this discussion it is clear that the engineer must use his judgment as to when it is necessary to apply the correction. An inspection of the formula will show that the lack of symmetry of the section is the most important consideration. The table given shows to what extent the effect of curvature enters into the correction.

See table page .

Borrow pits.- Borrow pits along side the roadbed, or any pits which are long and comparatively narrow, may be calculated as the cuts and fills are calculated. Where they are large and irregular and have been cross sectioned along intersecting range lines, the areas of the sections may be figured as irregular sections, or

Simpson's 1/3 Rule may be applied.

The following method of averaging the cuttings is often convenient and readily applied, where the pit has been divided into equal sized areas or blocks.



The calculation will be simplified by so staking out the pit that the area of each block will be a multiple of 27. In the figure the rectangles are all the same dimensions, 20' x 27'. Then one foot thick will give exactly 20 cu. yards. Multiplying 20 by the average depth gives the total number of cubic yards per block. Then adding the volume of the several blocks gives the yardage of the whole pit.

Where there are several blocks contiguous, it is evident that one corner height may be common to as many as four blocks. From this fact it is possible to simplify the calculation by combining the several blocks. See figure.

Let the small letters on the figure represent heights or cuttings and the sub-numeral the number of blocks to which the height is common. A = area of one prism 20 x 27.

$$\text{Total volume of pit} = V = \frac{A}{27}\left[\frac{(a_1 + b_1 + e_1 + j_1 + n_1 + k_1)}{4} + \frac{2(c_2 + f_2 + l_2 + m_2) + 3(d_3 + h_3) + 4g_4}{4}\right] = \text{in cubic yards.}$$

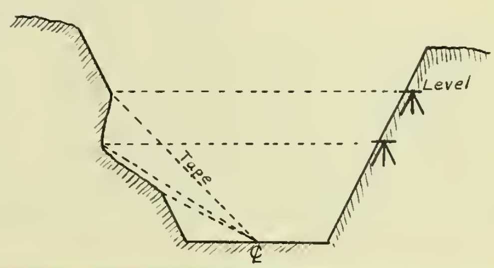
To avoid confusion a sketch should always be drawn, then those cuttings common to one corner added; next, those common to two corners added and the sum multiplied by 2; next, those common to three corners added and the sum multiplied by 3; finally, those common to four added and the sum multiplied by 4. The total summation is then divided by 4 and multiplied by A divided by 27 to get the result in cubic yards.

DITCHES.- In computing the quantities in berm and surface ditches, the end sections must be calculated as trapezoids or irregular sections, then the volumes obtained by the Average End Area method as in cuts and fills.

Cut ditches are often standard for the whole line. The cubic yards per station may be calculated, then multiplied by the length of ditches in stations.

OVERBREAK. - Overbreak is a difficult thing to compute with any great degree of accuracy. If the breakage is measured as the excavation proceeds there may be no difficulty in calculating the cross section as an ordinary irregular section. Judgment must be used in choosing the plusses of the cross sections. It is better in nearly every instance to measure the breakage by including it in a cross section rather than computing it as an additional local excavation. All cross sections of this nature should be plotted to scale on cross section paper.

Where the cuts are deep, slides and breakages may occur after the excavation is nearly to subgrade, and it may be found necessary to re-cross section the whole cut. If the cut is 50 or 60 feet deep and the breakage or slide has occured 15 or 20 feet from the top it may be impossible to measure distances out from the center, and the data must be obtained in the most ingenious way, then plotted and the distance scaled and area computed from the plotted cross section. One method of getting the field data is indicated in the diagram.



The plotted cross sections show the original section before slides, also the progress. At best, the measurement

and calculation of breakage is laborious and approximate, but since it is also a fruitful source of dissatisfaction and contention between the contractor and the company it should be given careful consideration, and always placed on record. Trautwine suggests, "To avoid trouble with contractors about the measurement of rock cuts, stipulate in the contract either that it shall conform with the theoretical cross section, or that an extra allowance of say about 2 feet of width of cut will be made, to cover the unavoidable irregularities of the sides." This might be a happy solution of the problem for the resident engineer if it were in general practise. Unfortunately, this is not the case and he must still continue to measure up and calculate breakage.

SHRINKAGE AND SWELL.- Where all quantities of earth are paid for in excavation and all the excavation can be satisfactorily measured, the shrinkage or swell will not enter into the calculations. Where embankments must be measured to give an estimate of the excavation it is necessary to know the swell and shrinkage factors, since some materials vary greatly in volume when loosened or broken up from their natural state.

There are so many conditions affecting shrinkage that the percentages can be only approximate. Moisture, water, and packing due to vehicles are the most important ones. Packing due to height or weight does not have any great effect.

Confusion frequently arises from a lack of understanding of the terms, swell, expansion, shrinkage, and settlement.

Earth when excavated or loosened from its natural bed or position will occupy a greater space, that is, it will "expand or swell", and temporarily make an embankment greater than the excavation from

which it came. If allowed to stand in its new embankment it shrinks or settles either naturally, that is, by its own weight and the effect of rains, etc., or it settles from the effect of vehicles used in handling it, such as scrapers, drags, wheelbarrows, etc.

Solid rock when broken up and deposited in an embankment will occupy from 25 to 75 per cent more space than before, the lower percentage applying where the pieces are placed by hand and approaching rubble masonry, the higher percentage applying where the pieces are dumped with little care as to how they are piled. The permanent swell or expansion for ordinary careful piling is taken from 40 to 60 per cent, say 50 per cent, for estimating. There is no considerable shrinkage of rock after placed in embankments.

Amount of Swell.- The swell or expansion of earth due to excavation varies with the kind of material and on an average is given by Gillette as follows:

Clean sand and gravel 14 to 15 per cent.
Loam, loamy sand and gravel 20 per cent.
Dense clay and dense mixtures of gravel and clay 33 to 50 per cent.
Extremely dense gravel and clay 50 per cent.

The swell of earth due to excavation is given as about 8 to 12 per cent under ordinary conditions and may be as great as 40 per cent.- Baker's "Roads and Pavements".

Amount of Shrinkage.- The total shrinkage of earth, sometimes called permanent or final contraction, is given as follows by Trautwine, Webb and others:

Gravel or sand	8 per cent.
Clay	10 " " .
Loam	12 " " .

Loose vegetable earth 15 per cent.

These percentages are based upon the volume in its original position.

These figures are to be used in estimating the amount of excavation necessary to make a given embankment. The usual American practise is to take the"total shrinkage" of ordinary earth as 10 per cent.

The rapidity of the shrinkage will depend largely upon the manner in which the material is handled. Gillette says that if rains are the only influence upon the embankment it will still be 8 per cent greater at the end of a year than the excavation from which it came; if an embankment is made with one horse carts or wheel scrapers, at the end of the work it will be 5 to 10 per cent less than the excavation from which it came and later may shrink 2 per cent more; or if made with wagons or dump cars, rapidly, and in dry weather, it will shrink 3 to 10 per cent in the year following the work, and little after that time.

Baker gives the following settlement for embankments after thay are completed.

For embankments built with wheel scrapers	1 to 2 percent for sand or gravel. 2 to 3 percent for clay or loam.
" " " " drag "	a little less than for wheel scrapers.
" " " " dump carts or wagons	a little more than for wheel scrapers.
" " " " Wheelbarrows	about 10 percent more than for wheel scrapers.

The amount of shrinkage caused by handling with drag ~~or~~ scrapers is given by Baker as follows:

8 per cent for gravel

9 " " " gravel and sand.

10 per cent for clay and clayey earth.

12 " " " loam.

15 " " " vegetable surface soil.

This is the amount that the embankment is compacted, measured on the basis of its original volume in excavation. Somewhat more shrinkage should be allowed for these materials when handled by wheel scrapers, wagons, cars, and wheel barrows, the allowance to be increased in the order given. This means that drag scrapers pack the material most and wheel barrows least.

These figures are for use in case it is required or desirable to stake out, or to cross section, the embankment for the additional size necessary to allow for shrinkage. They should not be used for setting finishing stakes after the embankment is practically complete as is sometimes done. The finishing stakes should take only the 1 to 3 per cent given above for settlement of embankmants after completion.

For shrinkage and settlement in steam shovel work the A.R.E. and M.W. Ass'n recommends the following:

"For green embankments, shrinkage allowance should be made for both height and width.

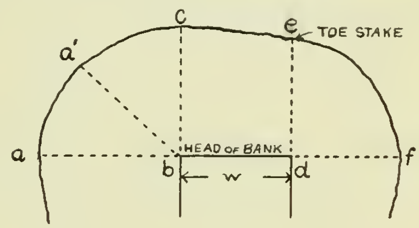
The shrinkage allowance should be as follows:

For black dirt, trestle filling	15 per cent.
" " " raising under traffic	5 " " .
" clay trestle filling	10 " " .
" " raising under traffic	5 " " .
" sand trestle filling	6 " " .
" " raising under traffic	5 " " . "

Loose Rock.- No reliable data can be given for swell or shrink-

age of "loose rock". It is capable of several definitions in the first place. Physically, it is so variable that the engineer must depend entirely upon his judgment in deciding upon what shrinkage factor to allow. The above will serve as a guide, perhaps.

HEAD OF BANK.- There is no accurate practical way of calculating the volume of a head of bank. The approximate methods, however, will give results which are not wide enough from the truth to make much difference in the estimate. The usual method is to consider each side of the head of bank, abc, and def, a quarter cone and the middle part, bcde, a wedge. b and d mark the width of roadbed and represent the head of bank line. c and e are in line with the respective shoulders of the roadbed.



For the quarter cone on the left the triangle on line bc is averaged with the one on line ab and this average triangle considered as generating the 1/4 cone; Or, the distance ab and bc are averaged and this average taken as the radius of the quarter cone whose height is the fill at b. The volume def is calculated similarly.

The following formula is sometimes used:

Volume abc = $0.0097hR^2$ (in cubic yards), where h is fill at b in feet, and R is $\frac{ab + bc}{2}$; or should there be an additional point a' taken, $R = \frac{ab + 2a'b + bc}{4}$.

The wedge bcde is calculated by averaging triangles at bc and ed and multiplying by the distance between, which is the width of the roadbed.

BRIDGE WORK

TRESTLES.- No trestle is permanent, yet trestles are frequently classified as permanent and temporary. The former applies to those

which are expected to be of service as long as the material will last, then will be renewed, while the latter refers to those which are used to aid in construction work only. The temporary trestles seldom have to be considered by the resident engineer unless the contractor is given a stipulated price for erecting. It is more common for the cost of themto be included in the contract price of the grading, or of the permanent work in which they are designed to aid.

In calculating the quantities of material entering into the permanent trestles, the caps for the piling or posts, and the decks, (all the timber structure above the caps) may be considered alike for both pile and frame trestles.

Piles.- For estimating piles it is usual to allow about ten feet for penetration unless the nature of the ground at the bridge site is well known. About two feet may be allowed for sqvaring ends, for brooming of the heads, and splitting under the hammer.

It is quite usual in pile driving specifications to find stated that the length of pile left in the structure shall constitute the pay length. This is calculated by subtracting the amount of cut off from the length put into the leads. Sometimes, however, it is customary to pay a small price per linear foot ~~paid~~ for the length cut off, in addition to the price per foot for the length left in the structure. Whether paid for or not the pileheads that are cut off should be measured as their length serves as a check.

If the piles are furnished by the contractor they are sometimes paid for on the basis of the estimated length in the bill of material. In this case the length of cut off and the length left in the structure are not essential in calculating the cost, but they should be made a matter of record to give information concerning penetration.

The limit of penetration is usually stated in the bridge specifications. The A.R.E. and M.W. Ass'n. gives the following pile driving limit as good practise. "Five blows of a 3000 pound hammer falling 15 feet (or the equivalent of this) are required to produce an average penetration of 1/2 inch per blow, except in soft bottom where specific instructions should be given".

The Engineering News formula is usually applied in finding the safe load a pile will carry.

$$T = \frac{2wh}{s + 1}.$$

T = safe load in pounds.

w = weight of hammer in pounds.

(Drop Hammer) h = height of fall of hammer in feet.

s = settling of pile under last blow, in inches.

For steam hammer $T = \frac{2wh}{s + 0.1}$

Frame Trestles.- When the "height of post" is spoken of in connection with a frame trestle the length of the vertical post from top of sill to bottom of cap is meant. The vertical posts may be considerably shorter than the side or batter posts. The latter may have a batter of from 1/12 to 1/4. In calculating the length, the longest side of the batter post should be taken, measured to the nearest 1/2 inch.

When superelevation is provided for in the length of posts all the posts may be of different length so each must be measured and calculated separately.

Frame trestles vary much in detail according to the designer, and few general rules for calculating can be given.

Bents for single story trestles are usually designed with from 18- to 24-foot or possibly 30-foot vertical posts, depending upon the lengths of large dimension timber available. Other stories are added

in the manner that seems most efficient and economical.

As best illustrating a common form of trestle the accompanying blue prints are inserted. These were prepared by the writer for choosing what he considered a good design for the ravine sections in question; and then for calculating the bills of material for each trestle. The large scale trestle was drawn accurately to scale off lengths to the nearest inch, which, in most cases is sufficiently accurate for a final estimate.

The maximum height of any vertical post was 24 feet, since 26 feet was about the limiting size of the available 12" x 12" timber.

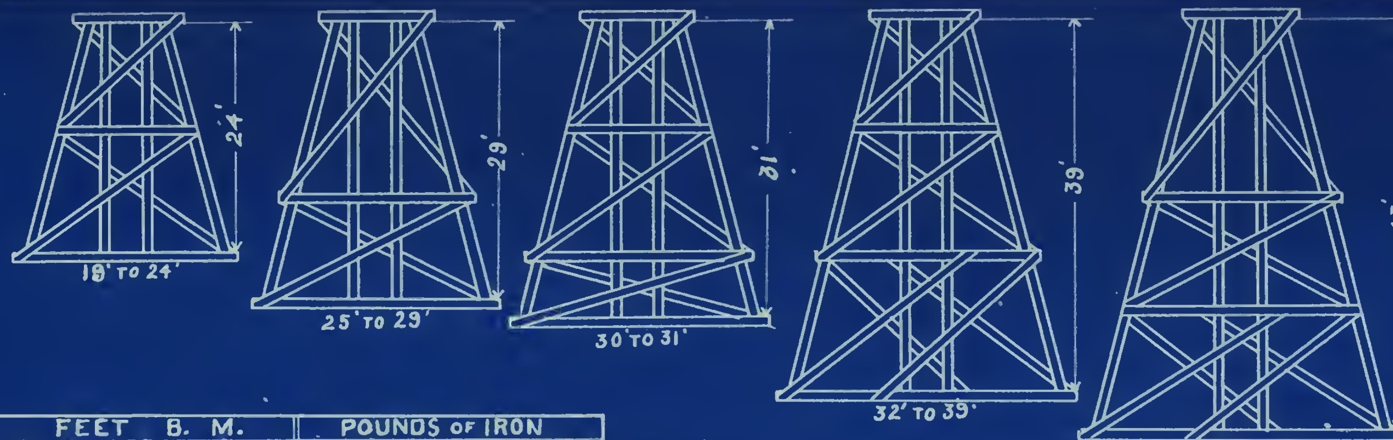
The diagrams and tables, it is hoped, are sufficiently clear so as to require no further explanation. As was intimated above, they are not general, but will offer suggestions as to how calculations may be made for other standard designs.

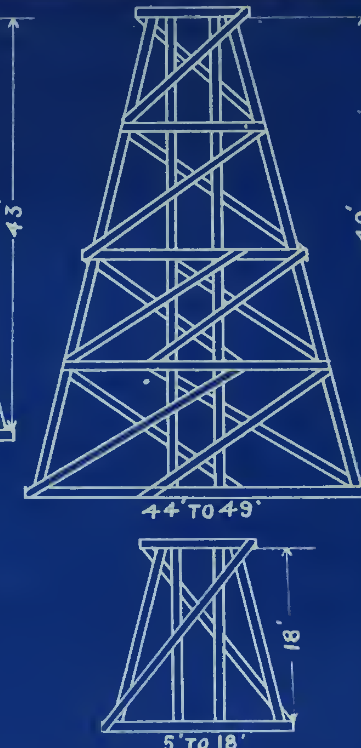
Superelevation may be provided for (1) by placing corbel blocks under the outside stringers, (2) notching the caps on the inner side to lower the inside stringers, (3) placing shims or wedges between the ties and stringers on the outside, or between the base of the outer rail and the tie, (4) tilting the whole trestle, inclining the sill, and (5) making the posts of different lengths. Combinations of these various methods may also be used.

Method 5 was used in the diagram shown; and a table is given for the variations in lengths of the different posts of a bent corresponding to the superelevations for the different degrees of curve.

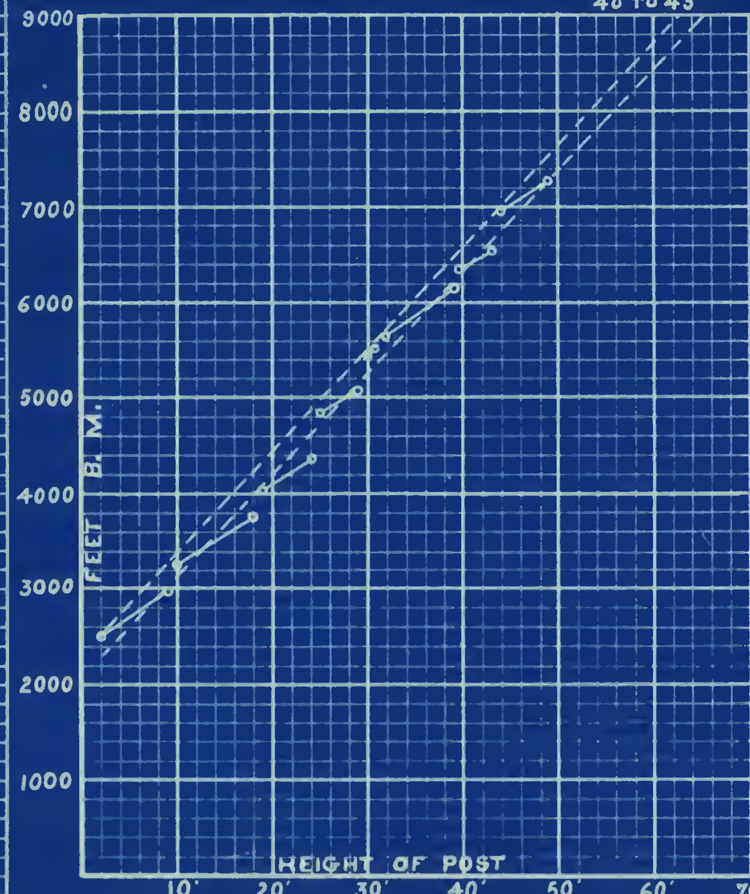
All timber on trestle work, except piles, is calculated in units of 1000 feet B.M. The iron, including bolts, washers, spreaders, etc., is paid for by the pound, and so calculated.

MASONRY.- Pedestals, abutments, culverts and all other masonry struct-





SILL TO CAP	FEET B. M.				POUNDS OF IRON			
	BENT	LONG. & LONG. BR.	DECK	TOTAL	BENT	LONG. & LONG. BR.	DECK	TOTAL
2 BK. BT.	1648		1543	3191	122		138	260
1	980		"	2523	61		"	199
2	960		"	2503	"		"	"
3	1008		"	2551	"		"	"
4	1068		"	2611	"		"	"
5	1191		"	2734	64		"	202
6	1256		"	2799	"		"	"
7	1309		"	2852	"		"	"
8	1369		"	2912	"		"	"
9	1422		"	2965	"		"	"
10	1487	225	"	3255	"	13	"	215
11	1540	230	"	3313	"	"	"	"
12	1605	230	"	3378	"	"	"	"
13	1658	235	"	3436	"	"	"	"
14	1742	240	"	3525	"	"	"	"
15	1792	245	"	3583	"	"	"	"
16	1860	245	"	3648	"	"	"	"
17	1913	250	"	3706	"	"	"	"
18	1978	255	"	3776	"	"	"	"
19	2161	353	"	4057	114	"	"	265
20	2226	358	"	4127	"	"	"	"
21	2274	363	"	4180	"	"	"	"
22	2339	368	"	4250	"	"	"	"
23	2392	373	"	4308	"	"	"	"
24	2457	378	"	4378	"	"	"	"
25	2698	610	"	4851	97	32	"	267
26	2758	610	"	4911	"	"	"	"
27	2811	615	"	4969	"	"	"	"
28	2871	615	"	5029	"	"	"	"
29	2924	620	"	5087	"	"	"	"
30	3175	723	"	5441	148	"	"	318
31	3223	728	"	5494	"	"	"	"
32	3348	728	"	5619	174	"	"	344
33	3401	733	"	5677	"	"	"	"
34	3466	733	"	5742	"	"	"	"
35	3524	738	"	5805	"	"	"	"
36	3589	743	"	5875	"	"	"	"
37	3647	743	"	5933	"	"	"	"
38	3777	748	"	6068	195	"	"	365
39	3834	753	"	6150	"	"	"	"
40	4039	758	"	6340	"	"	"	"
41	4087	758	"	6388	"	"	"	"
42	4169	763	"	6475	"	"	"	"
43	4227	763	"	6533	"	"	"	"
44	4551	867	"	6961	271	"	"	441
45	4604	872	"	7019	"	"	"	"
46	4681	877	"	7101	"	"	"	"
47	4729	882	"	7154	"	"	"	"
48	4787	882	"	7212	"	"	"	"
49	4843	887	1543	7275	271	32	138	441



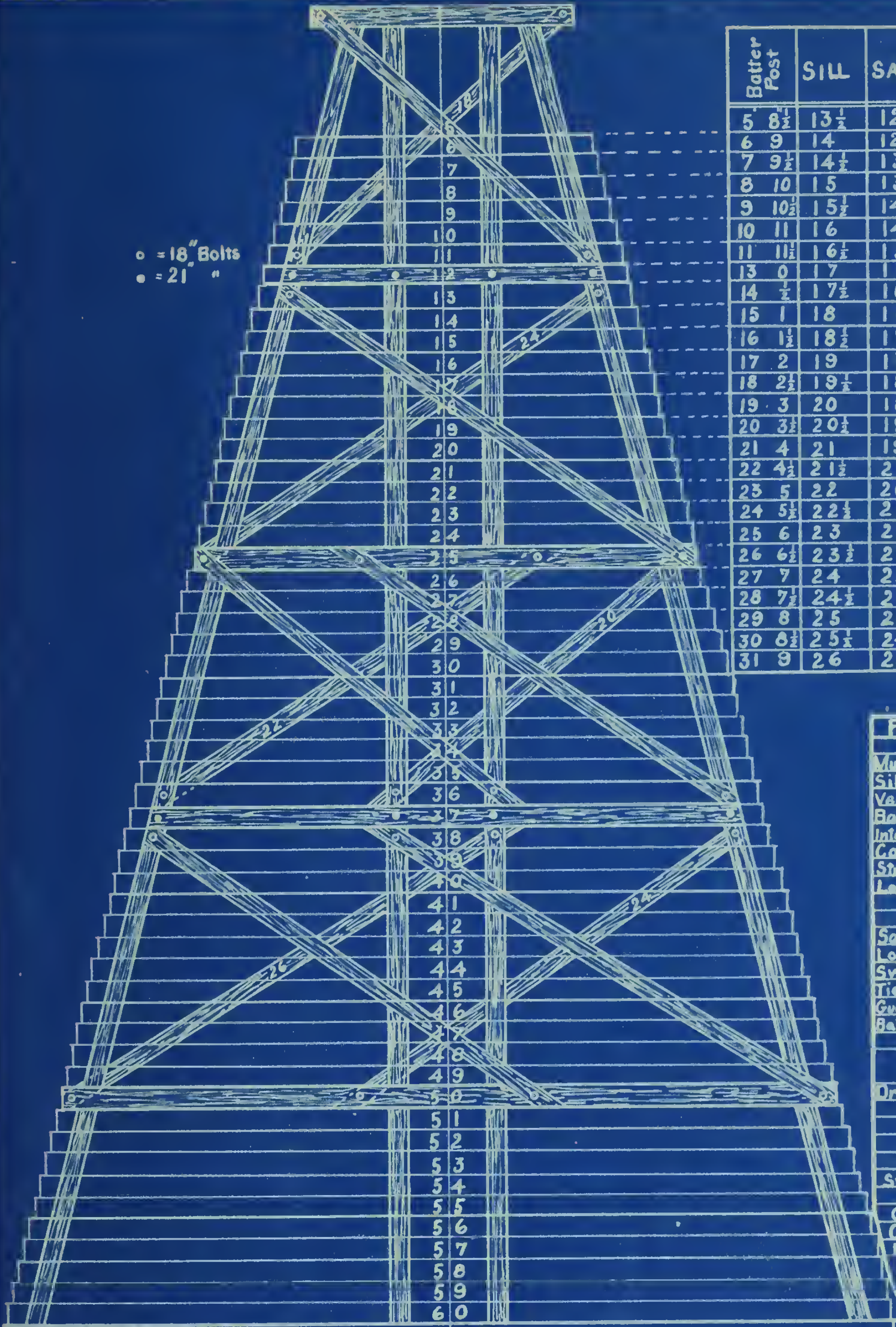
Equation of Upper Line M = 2288 + 105.8 H
Approx. Equation M = 2300 + 106 H

Note: Maximum length of timbers upon which this table is based is 26 feet.
For making estimates of trestles from profiles subtract three feet from distance ground to subgrade to get length of trestle post.

TABLE showing material required for trestle bents up to and including 49 feet in height, and DIAGRAM for estimating F.B.M. in bents of greater heights.

DRAWINGS represent designs upon which table is based.

J.C.B.



SCALE: 1 inch = 8 feet

Batter Post	SILL	SASH	Long. Brace Vertical	Long. Brace Batter	Sway Brace To Sash	Sway Brace To Sill	Ver. Post
5 8½	13½	12	14.0	14.0	13.2	14.8	5
6 9	14	12½	14.3	14.4	13.9	15.5	6
7 9½	14½	13	14.8	14.9	14.6	16.2	7
8 10	15	13½	15.3	15.4	15.4	17.0	8
9 10½	15½	14	15.8	16.0	16.2	17.8	9
10 11	16	14½	16.4	16.6	17.0	18.6	10
11 11½	16½	15	17.0	17.2	17.9	19.5	11
13 0	17	15½	17.7	17.9	18.7	20.4	12
14 ½	17½	16	18.4	18.7	19.6	21.2	13
15 1	18	16½	19.1	19.4	20.5	22.1	14
16 1½	18½	17	19.9	20.2	21.4	23.0	15
17 2	19	17½	20.6	21.0	22.3	23.9	16
18 2½	19½	18	21.4	21.8	23.3	24.8	17
19 3	20	18½	22.2	22.7	24.2	25.8	18
20 3½	20½	19	23.0	23.5	25.2	26.7	19
21 4	21	19½	23.9	24.4	26.1	27.6	20
22 4½	21½	20	24.7	25.3	27.0	28.6	21
23 5	22	20½	25.6	26.1	28.0	29.6	22
24 5½	22½	21	26.4	27.0	29.0	30.5	23
25 6	23	21½	27.3	28.0	30.0	31.5	24
26 6½	23½	22	28.2	28.9	31.0	32.5	25
27 7	24	22½	29.1	29.8	31.9	33.4	26
28 7½	24½	23	30.0	30.7	32.9	34.4	27
29 8	25	23½	30.9	31.7	33.9	35.4	28
30 8½	25½	24	31.8	32.6	34.9	36.4	29
31 9	26	24½	32.7	33.5	35.8	37.3	30

PIECE	SIZE	FORMULA	B.M.
		N = number spans	
Mud Blocks	12 × 12 × 4½	10 per Bent	54
Sills	" —	L = 11 + (h ÷ 2)	
Ver. Posts	" —	Length = h	
Bat. "	" —	L = h + (h × ⅛) + 6"	
Inter. Caps	" —	L = 11 + (h ÷ 2)	
Caps	12 × 12 × 12	1 per Bent	144
Stringers	8 × 16 × 26	3 × N	277⅓
Longitud's	4 × 10 × 28	N at Sash	93⅓
"	6 × 10 × 28	½ N at Inter. Cap	140
"	"	" " Sill	
Sashes	3 × 10	See Figure	
Long. Brace	3 × 10	" "	
Sway "	3 × 10	" "	
Ties	8 × 8 × 10	11.2 N	53⅓
Guard Rails	6 × 8 × 22	1.3 N	88
Ballast Boards	3 × 10 × 12	1 per Bank Bent	30
" "	3 × 10 × 16	1 " " "	40
			Wt. per 100 pcs
Drift Bolts	¾ × 24	4 per Cap; 4 per I. Cap and 2 per Bent	295
" "	¾ × 20	8 per Sill	246
" "	¾ × 15	3 per 28' Long; 2 per short Long.	185
Sw. Br. "	¾ × 21	See Figure	294
"	¾ × 18	" "	258
G.R. "	¾ × 16	½ number of Ties	233
Chord "	¾ × 31	Odd N × 6 + 2; Even N × 6	417
Boat Spks.	½ × 14	½ number of Ties	90.9
" "	½ × 10	4 per Sw. Br.; 6 per Long	42.1
" "	½ × 12	4 per Inter. Cap	83.3
C.I. Sep.	2 × 4	2 - Chord Bolt	510
O.G. Wash	1 × 4	2 for all but G.R. Bolts	150
C.I. "	¾ × 3	2 per G.R. Bolt	110

SUPERELEVATION OF OUTER RAIL

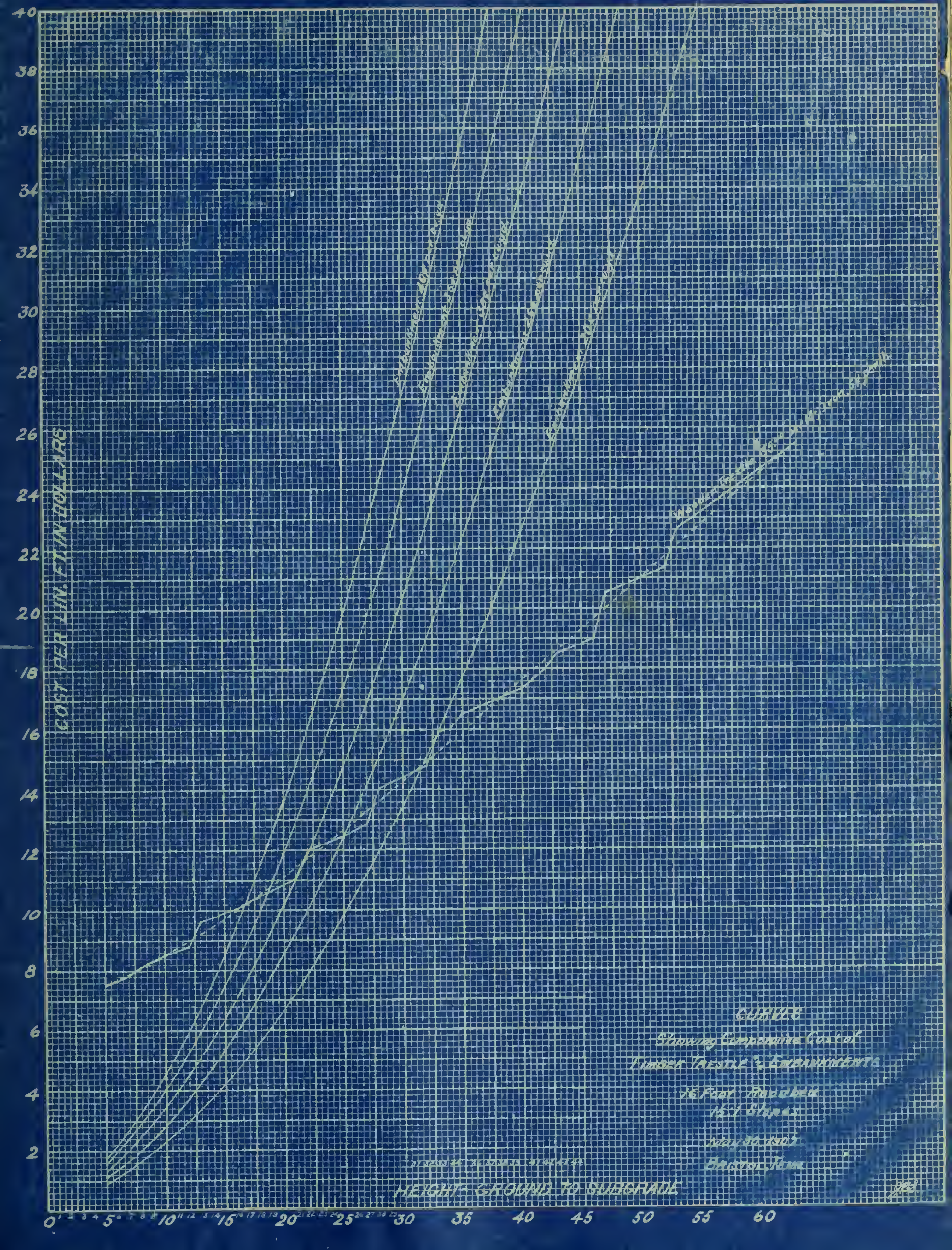
CURVE	H. R. RY.	B. M. RY.
1 Degree	1½ inches	½ inches
2 "	2¼ "	¾ "
3 "	3 "	1¼ "
4 "	3¾ "	1½ "
5 "	4½ "	2 "
6 "	5¼ "	2⅜ "
7 and over	6 "	2¾ "
8 " "		3 "

CURVE	a	b	c	d	e	f
1 Degree	2.64	2.16	1.60	0.16	0.40	1.20
2 "	3.96	3.24	2.40	0.24	0.60	1.80
3 "	5.28	4.32	3.20	0.32	0.80	2.40
4 "	6.60	5.40	4.00	0.40	1.00	3.00
5 "	7.92	6.48	4.80	0.48	1.20	3.60
6 "	9.24	7.56	5.60	0.56	1.40	4.20
7 and over	10.56	8.64	6.40	0.64	1.60	4.80
	For H.R.RY.					

V. & S. W. RY.

DATA FOR ESTIMATING MATERIAL IN STANDARD FRAME TRESTLES

June 28, 1907.


COST PER LIN. FT. IN DOLLARS
HEIGHT GROUND TO SUBGRADE
CURVES
Showing Comparative Cost of
Timber Trestle & Embankments
16 Foot Roadbed
1½-1 Slopes
May 30 1907
Bristol, Tenn.
40
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60

ures, having distinct foundations or footings are best considered in two parts for calculation, the footings and the super structure.

The footings are often quite regular in plan and also in thickness if resting upon the earth. They may be easily figured then by dividing them at the angles into prisms and wedges. If they cannot be divided into prisms, they should be divided into prismoids and the prismoidal formula applied.

Should the footing rest upon rock the under surface may be very irregular if the rock has not been blasted out. Elevations having been taken before the laying of the foundation began, the average thickness of the footing is determined and the volume found as in borrow pits. (See method of measuring borrow pits). Footing masonry should be kept separate from the superstructural masonry. It sometimes is paid for at a different price.

For the part above the footing it will be necessary to study carefully the geometry of the solid structure, particularly of those having wing walls, battered surfaces, and curved outlines. They should then be divided into the simplest solids such as prisms, wedges, pyramids, or into prismoids such that the middle area can be found. All curved areas may be reduced to, and calculated, either as circles, parabolas or ellipses, or as segments of these figures.

The amount of material in masonry structures should be calculated by the Prismoidal Formula, since it is just as easily applied as the End Area method with the Prismoidal Correction.

The Prismoidal Formula considers the prismoid composed of a prism, wedge, and pyramid, and frequently it will be just as easy to consider these components by themselves as to calculate a middle area of the prismoid and apply the formula to the whole.

(See list of convenient formulas in Chapter XVII.)

Reinforcing bars are paid for in the price for masonry and need not be calculated in this connection, but should be estimated in weight for calculating the haul. (See haul on Materials).

Wooden culverts are paid for and calculated in 1000 feet B.M.

Culverts other than masonry and timber are estimated, monthly, in linear feet or in per cent of total length until finally completed. When finished the estimate is returned as complete, the office arranging payment as per contract.

Bulkheads, cofferdams, caissons, cribs, etc., if of timber are calculated in 1000 feet B. M. units.

HAUL OF MATERIAL.- Haul is usually based upon the ton-mile unit. The price is fixed at so much per ton hauled one mile. The distance should be measured along the actual route travelled and to the nearest 100 feet. It is poor practise to depend upon supposed section, quarter section, or property, lines as giving reliable distances, or even upon the popular distance as given by the "oldest resident".

It is sometimes specified that "ton mile pay haul" shall not be paid on materials hauled less than one mile.

Following are some of the convenient units and weights of materials likely to be hauled:

Portland Cement	5 1/4 bbls. (376# per bbl. net weight.)	per ton.
" "	22 sacks	" " .
Natural Cement	7 bbls. (300# per bbl. net weight)	" " .
2 jute sacks or 3 paper sacks are equivalent to one barrel.		
Sand	25 cu. ft.	per ton.
Brick	400	" " .
Broken stone	20 cu. ft.	" " .
Lime stone	12 1/2 " "	" " .
Sandstone	14 " "	" " .
Timber	500 feet B.M.	per ton.
Barb wire	20 spools	" " .

Johnson Reinforcing Bars.

1/2 inch bar	0.18 sq. inch net sect.	weight	0.64 lbs. per ft.
3/4 " "	0.37 " " " ".	"	1.35 " " ".
7/8 " "	0.55 " " " "	"	1.95 " " ".
1 " "	0.70 " " " "	"	2.70 " " ".
1 1/4 " "	1.07 " " " "	"	4.00 " " ".

Cast iron pipe for culverts. 2240 pounds per ton.

24 inch pipe,	12 foot lengths weigh	3000 pounds each.
36 " ",	" " " "	4800 " ".
48 " ",	" " " "	8400 " ".
60 " ",	" " " "	13000 " ".

These weights are for extra heavy pipe; lighter pipe runs about 20% less.

See tables in Chapter XVIII for weights of track materials.

OVERHAUL.- There are two well known methods of calculating overhaul, the analytical method and the mass curve method. The former, although theoretically exact, is laborious if carried out to give close results and is scarcely consistent with the comparatively crude and more or less approximate field measurements. The mass curve gives consistently accurate results if plotted to a reasonably large scale, and in addition gives a diagram which makes it possible to comprehend a considerable part of the line at once. It therefore gives a more intelligent comparison, and makes possible a wiser distribution, of the earth work quantities.

For estimating overhaul on newly located lines, and for monthly estimates on construction, the mass diagram, without question, gives consistently close results; and there are few instances where it will not suffice for the final. The writer feels that in ordinary graduation the analytical method is confusing and unwieldy, and does not consider it sufficiently popular to present it in this work.

The mass curve is plotted beginning at some point on the residency across which no material is to be hauled, e.g., at a bridge, a

division between residencies, or between contracts. The zero line may be taken as the horizontal line passing through such a dividing point. The horizontal distances are plotted to the same scale as the accompanying profile; the vertical distances or ordinates represent algebraic summations of the quantities in cubic yards, beginning at the dividing point above mentioned. It is usual to plot excavations upward and embankments downward and in the direction of the profile, either directly below or above it.

The accompanying problems will make the construction clear.

Properties.- Following are the most important properties of the Mass Curve:

Maximum or minimum points on the curve represent changes from cut to fill or vice versa.

Maximum and minimum points fall vertically in line with grade points.

If plotted as indicated above, curve concave upward indicates change from fill to cut.

If plotted as suggested above, curve convex upward indicates change from cut to fill.

If a horizontal line is drawn cutting the curve at two points, the cuts will make the fills between those points,- not considering swell or shrinkage.

The area between any horizontal line and the curve represents the total haul of material between the points on the curve touched by the horizontal line.

Definitions.- Haul is the product of the material hauled (cu.yd.) and the distance hauled, and is measured in "yard stations" usually, that is, 10 cu. yds. hauled 10 sta. gives 100 yard-stations.

Freehaul limit is the specified distance within which no price is paid for hauling. In the mass curve it is defined by drawing a horizontal line of the specified length to scale which just touches two points of the curve.

Freehaul is the amount of material within this limit multiplied by the distance hauled and is represented by the area between the curve and the horizontal line of freehaul length. Freehaul is often spoken of as the amount or yardage only.

Overhaul is the product (yd.-sta.) of the amount of material hauled more than the freehaul distance and the distance hauled. An overhaul limit, or limit of profitable haul, is usually intended to mean the distance beyond which the cost of the haul is greater than the excavation price, that is, beyond this point it would be cheapar to borrow material, and waste the material at the original excavation. This may be made clearer by the following formula and example:

Let P = price per cu. yd. of excavation or borrow.

p = price per yd.-station of overhaul.

d = freehaul limit distance, in stations.

l = limit of profitable haul in stations.

Then $(l - d)p = P$, or cost of haul = cost of excavation, or

$$l = \frac{P + dp}{p}.$$

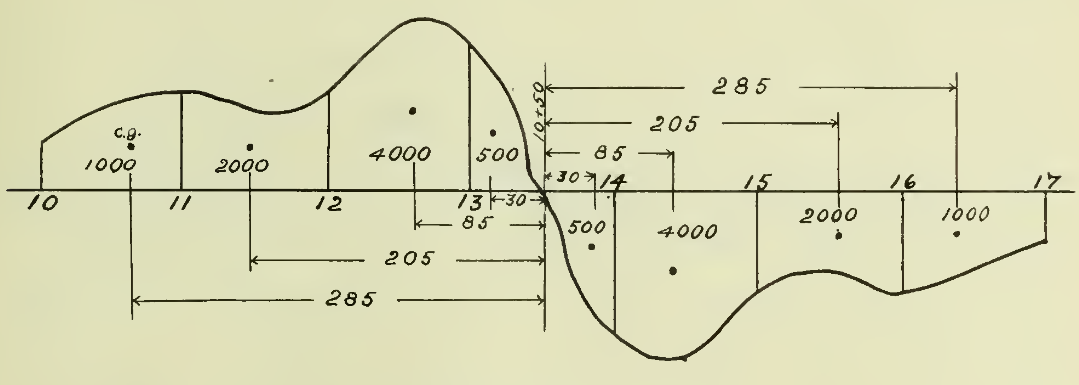
Example: P = 20¢, d = 3 sta., p = 1¢, then $l = \frac{20 + (3 \times 1)}{1} = 23$ sta.

The overhaul limit as defined above should govern in the absence of specifications to the contrary. It is sometimes specified that the overhaul limit shall be measured from center of gravity to center of gravity, that is, in the problem above under this specification 23 stations would be the distance c.g. of cut to c.g. of fill

and a large portion of the material would necessarily have to be hauled much farther, a distance that would be unprofitable. In any case, the distance c.g. of excavation to c.g. of embankment is the basis for calculation but this distance should be less than the limit of profitable haul.

This same interpretation should apply to the freehaul distance, that is, the freehaul distance should refer to the extreme limits and not c.g. to c.g. See problem given below, page 135.).

A method of calculating overhaul sometimes used but which should receive little consideration is given as follows: The product of the total yardage and the freehaul limit is subtracted from the product of the total yardage and the average displacement to give the overhaul. In a case where a heavy cut and fill are very large near the grade point and smaller farther away from the grade point the distance of c.g. of excavation to c.g. of embankment may be less than the freehaul limit and there will be no overhaul, although some of the material is hauled a considerable distance beyond the freehaul limit.



(SEE FOLLOWING CALCULATIONS)

Station	Cen. Gravity to Grade pt.	Quantity	Haul
10 to 11	285'	1000 cu. yd.	2850.00 yard stations.
11 to 12	205	2000 " "	4100.00 " "
12 to 13	85	4000. " "	3400.00 " "
13 to 13 + 50	30	500 " "	150.00 " "
10 to 13 + 50	140	7500 " "	10500.00 " "
i3 + 50 to 17	140	7500 " "	10500.00 " "
	280		21000.00

Center of Gravity of Exc. to c.g. of Emb. = 280'

Then total haul = 280 x 7500 = 21000 yard stations. If 300 feet is assumed as the freehaul distance, then according to the method just stated above, that is, (Dist. c.g. of Exc. to c.g. of Emb.) x (Total yardage) minus (Freehaul distance)(Total yardage) = Overhaul, the limiting amount of Freehaul is 300 x 7500 = 22500 yard stations. Therefore, there is no Overhaul according to this method of calculating.

It is also evident from this problem that there will be no Overhaul if the Freehaul distance is measured as 300 feet c.g. of Exc. to c.g. of Emb., instead of 300 feet extreme limit of freehaul, even though some of the material is hauled 700 feet.

Working the problem using 300 feet as the freehaul extreme limit we have: Station 12 and station 15 are the freehaul limits, no ~~no~~ pay haul being allowed on material between those points, nor on any other material as it is being hauled between those points.

Stations	c.g. to c.g.	Freehaul Dist.	O.H.Dist.	Cu.Yd.	O.H.
10 to 11 to 16-17	5.7 sta.	3.0 sta.	2.7 sta.	1000	2700
11 to 12 to 15-16	4.1 "	3.0 "	1.1 "	2000	2200
		Total yard-stations	=		4900

If the excavation price is 20¢ per cu. yd. and the Overhaul price 1¢ per yard-station, then the cost is:

7500 cu. yds. @ 20¢	=	$1500.00
4900 yd. sta. @ 1¢	=	49.00
		1549.00

The pay haul therefore adds about 3 1/3 per cent to the cost,- a considerable sum upon which to argue for this method.

The recommendations of the A.R.E. & M.W. Ass'n. are given below, indicating good practise in calculating Haul and Overhaul.

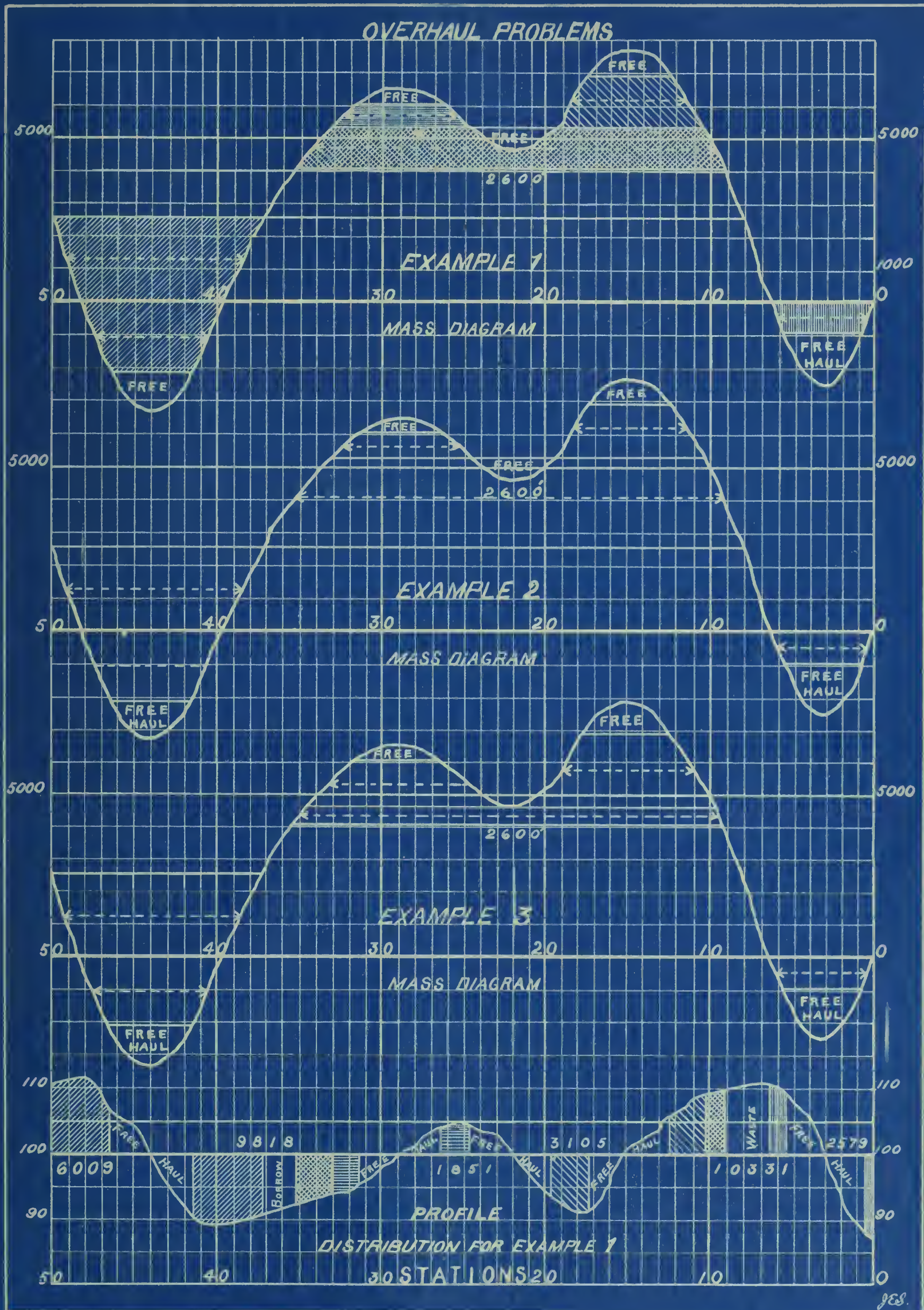
"The limits of freehaul shall be determined by fixing on the profile two points - one on each side of the neutral grade point - one in excavation and the other in embankment, such that the distance between them shall equal the specified freehaul limit and the included quantities of excavation and embankment balance. All haul on material beyond this freehaul limit shall be estimated and paid for on the basis of the following method of computation, viz.:

All material within this limit of freehaul shall be eliminated from further consideration.

The distance between the center of gravity of the remaining mass of excavation and the center of gravity of the resulting embankment, less the limit of freehaul as above described, shall be the length of the overhaul, and the compensation to be rendered therefor shall be determined by multiplying the yardage in the remaining mass as above described by the length of the overhaul. Payment of the same shall be by units of one cubic yard hauled one hundred (100) feet."

A problem has been worked in several ways from the mass curve, and comparisons made which will aid in making clear the use of the

mass curve, and the difference of results due to the various methods. No attempt has been made to show all that can be accomplished with this curve, but from the suggestions given all of the usual problems can be calculated.


OVERHAUL PROBLEMS
EXAMPLE 1
MASS DIAGRAM
FREE
FREE HAUL
2600
5000
1000
50
40
30
20
10
0
EXAMPLE 2
MASS DIAGRAM
EXAMPLE 3
MASS DIAGRAM
110
100
90
6009
9818
1851
3105
10331
2579
BORROW
WASTE
PROFILE
DISTRIBUTION FOR EXAMPLE 1
STATIONS
J.E.S.

OVERHAUL PROBLEMS

EXAMPLE 1. – Limit of Overhaul 2600'

STA. to STA.		FREEHAUL	DIST.	OVERHAUL CU. YDS.	OVERHAUL YARD-STA.	WASTE CU. YDS.	BORROW CU. YDS.	TOTAL EXC.
0+50	5+50	1719						1719
0+30	6+00		0.7	860	602			860
6+35	9+30					4000		4000
9+80	34+30		19.5	1320	25740			1320
11+20	18+40		2.2	1580	3476			1580
12+30	17+30	852						852
19+65	24+65	673						673
26+45	31+45	448						448
25+50	32+30		1.8	730	1314			730
35+30	37+00						1311	1311
38+40	49+20		5.8	2689	15596			2689
40+50	47+50		2.0	2200	4400			2200
41+50	46+50	1120						1120
TOTALS		4812		9379	51128	4000	1311	19502

EXAMPLE 2a – C.G. to C.G. of Overhaul 2600'

STA. to STA.		FREEHAUL	DIST.	OVERHAUL CU. YDS.	OVERHAUL YARD-STA.	WASTE CU. YDS.	BORROW CU. YDS.	TOTAL EXC.
0+50	5+50	1719						1719
0+30	6+00		0.7	860	602			860
6+35	8+20					2690		2690
9+25	35+25		21.0	2630	55230			2630
11+20	18+40		2.2	1580	3476			1580
12+30	17+30	852						852
19+65	24+65	673						673
26+45	31+45	448						448
25+50	32+30		1.8	730	1314			730
38+40	49+20		5.8	2689	15596			2689
40+50	47+50		2.0	2200	4400			2200
41+50	46+50	1120						1120
		4812		10689	80618	2690		18191

EXAMPLE 2b

Same as Ex. 2a except there is no Long Haul.

STA. to STA.		FREEHAUL	DIST.	OVERHAUL CU. YDS.	OVERHAUL YARD-STA.	WASTE CU. YDS.	BORROW CU. YDS.	TOTAL EXC.
6+35	10+50					5320		5320
33+10	37+00						2631	2631
		4812		8059	25388	5320	2631	20822

EXAMPLE 3. – Limit of Freehaul 2600'. All of cut Sta. 22 to Sta. 29 hauled ahead.

STA. to STA.		FREEHAUL	DIST.	OVERHAUL CU. YDS.	OVERHAUL YARD-STA.	WASTE CU. YDS.	BORROW CU. YDS.	TOTAL EXC.
0+50	5+50	1719						1719
0+30	6+00		0.7	860	602			860
6+35	9+30					4000		4000
9+60	34+80		20.2	647	13069			647
10+30	18+80		2.9	2253	6534			2253
12+30	17+30	852						852
26+45	31+45	448						448
24+75	33+05		3.3	1403	4630			1403
35+30	37+00						1311	1311
38+40	49+20		5.8	2689	15596			2689
40+50	47+50		2.0	2200	4400			2200
41+50	46+50	1120						1120
		4139		10052	44831	4000	1311	19502

	Example 1	Example 2a	Example 2b	Example 3
OVERHAUL	$ 511.28	$ 806.18	$ 253.88	$ 448.31
EXCAVATION	4095.42	3820.11	4372.62	4095.92
	4606.70	4626.29	4626.50	4543.73

Freehaul 500'
Overhaul price 1¢ per Yd.-Sta.
Exc. price 21¢ per cu. yd. 9.C.B.

CHAPTER X

REPORTS AND RECORDS

The various reports will not be discussed in detail. It is intended to give general forms and only those with which the resident engineer has most to do. The railway company often has its special blamk forms or standards for which the resident engineer should make requisition.

DAILY.- On heavyconstruction work such as bridges, tunnels and steam shovel work it is often desidable and sometimes required that daily progress be reported to the chief engineer.

Bridges.- Progress on steel bridges and masonry may be reported in a general way as so many girders or members in place and so many yards of masonry or concrete laid, or it may be reported by force report, a statement being made of the number of men, teams, engines, etc. at work. These progress reports are obtained by the bridge or masonry inspector who records them in his field book and gets them in shape to send to the chief engineer.

For reporting pile bridges a more elaborate form is desirable. Although the progress on these structures may not be reported to the chief engineer daily, a daily record is kept. The Pile Recorder keeps the records, but the Resident Engineer is responsible and must see that the proper form is used.

Below is given a common form.

PILE RECORD

PILE BRIDGE No. 114.24	LENGTHS RECORDED				PENETRATION		AV. HAMMER	DESCRIPTION	Date
Pile	Billed	Put in Leads	Cut Off	Pay	TOTAL	Last 5 Blows	DROP, Last 5 Blows.		REMARKS
BENT No. 1	Sta. 17+42.5								
A	26	26	2	24	12.6	2.5	27	White Oak	Bents lettered Left to Right Thus:
B	etc.								Ⓐ Ⓑ Ⓒ Ⓓ
C									Kind of Soil Splitting of Piles
D									Blasting necessary Changed from Billing
									etc.
BENT No. 2	Sta. 17+57.3								Names of - Contractor
A									Foreman Inspector
									Res. Engr.

Tunnels.- Tunnel progress is conveniently reported in linear feet. The manner of driving, whether as a full heading, upper section, lower section, etc. should be noted. The exact bore of the tunnel being known from the plan, the yardage is easily calculated. Force report is added to show comparative results, either daily or per capita.

Steam Shovel Excavation.- Steam shovel work is reported daily in the following manner. The report is not usually required to be sent in before the end of the week.

STEAM SHOVEL REPORT

DATE	STATION		MEN	TEAMS	ENGINES	CARS	Yards moved	________ CONTRACTOR
	EXC.	EMB.					Since Last Report	REMARKS
								H. Carlson, foreman.
July 3/04	27+25	8+50 to 10	30	1	2	22	670	4-Yard cars used. Rain
etc.								Breakdowns Blasting
								Insufficient force etc.
								Res. Engr.

Track Laying.- The resident engineer may have to look after the track laying, in which event he makes daily reports of the progress more often, however, he certifies to the report made out by the track foreman.

These reports are always made on standard forms furnished by the company.

Cars of Material Received and Delivered.- It is veryimportant that accurate record be kept of all cars received and unloaded. The resident engineer should see that they are always unloaded before demurrage charges accumulate, the limit being 48 hours from receipt of car. Especially does this apply to foreign cars. The freight bills should be returned to the office without delay. Careful checks must be nade upon all material as soon as received and any deficiency reported at once.

The record of material received should be in detail. All important notes and headings as they appear on the invoice and waybill should be copied.

CARS RECEIVED & UNLOADED											
DATE			CAR		WAY-	SHIPPED		CONTENTS	TRAFFIC	SHORT-	REMARKS
REC'D	UNLOADED	EXP BILL RETURNED	INITIAL	No.	BILL No.	FROM	TO		CHARGES	AGES	
Mar 2/03	Mar. 3/03	Mar. 5/03	A.B.& C	34790	432	Chicago	Truxton	100 bbl Port. Cement	$ 15.40	O.K.	
etc.											

This is complete and convenient to refer to in case any question arises later. Questions frequently arise due to the fact that from the time the material is ordered until it is unloaded, a great many parties must have a part in the handling, recording and tracing of it.

WEEKLY REPORTS.- In addition to the above mentioned reports, the most important one is the Force Report. This is a record of the force employed in the execution of the work and is usually given as an average for the week. It may be made up from observations made by any member of the party, usually the rodman, as he passes along the line. He may get the force from the contractor but should check from observation when possible. The report is intended to

assist the railway company in drawing inferences as to the present and future progress of the work. If the rodman only guesses at the force employed, as is too often the case, or assumes that it is the same this week that it was last week, without verifying his assumption, the report will be of little use.

The report should show each contractor's gangs separately and should indicate the location of each piece of work under way.

A. B. & C. Ry. Co.
FORCE REPORT

Week ending .... Residency No. ....

Mile	Sta	to Sta	Contractor	Cu. Yd.	Teams Haul	Teams Extra	Men	Cars	Wag.	Wheel	Slips	Remarks
1	27	40	Giffin & O'brien	700	6	2	12			6		Ave. force for 5 days
2	65	92	Henry & Ryan	1500	8	10	18		8			Rained July 6th. Grading machine - 5 days
etc.												

MONTHLY REPORTS.- Of the monthly reports those which take up most time in preparation and give the resident engineer most anxiety are the estimates of work performed by the contractor. As these have been considered under Calculating Quantities only the typical blank forms will be indicated here.

Detail Sheet.- The detail sheet is filled out by the resident engineer from the calculated quantities, each item being placed by itself and the station of its location given. The sheet should contain the Residency number, the name of the contractor, usually both general and sub-contractors, the mile or section of the line, the date and certificate of the resident engineer. Some roads require that the assistant resident engineer also certify to the estimate.

Some railways use small size detail sheets large enough only to provide for a single mile; others use sheets large enough for the entire residency, or for all work on the residency being performed

by one contractor. The form shown will make clear the essentials.

It is practise with some companies to give the resident engineer the contract prices and require him to make up the cost sheet. He places upon the cost sheet the totals of the items found on the various detail sheets, making out a cost sheet for each contract. The proce of each item is multiplied by the respective units and the total cost of work entered upon the sheet. From this amount the retained percentage, usually 10% or 15% is deducted giving the estimate to be allowed. The payment for the previous month is then deducted leaving the estimate due for the month.

PROGRESS PROFILE.- The progress profile is a record of all work done to date and should show alinement, size, kind and exact location of bridges, culverts, important buildings, station grounds, main track, side track and wyes, depth of piles, and the culture along the line. Progress of grading is indicated by giving a different color to each month's work as shown in the legend of the accompanying sample profile. The profile is colored to date soon after the monthy estimate is sent in, then forwarded to the chief engineer who transfers the data to his office progress profiles before returning it. For mailing purposes it is sometimes more convenient to make the profile upon tissue profile paper or profile cloth.

PAY ROLL AND EXPENSE ACCOUNT.- The Pay roll and the Expense Account are required to be sent in at the end of the month. Each is made upon a special blank form. The former will generally consist of the salary roll of the engineering party. The latter consists of the allowable monthly expenses of the engineering party, such as meals, R. R. fare, livery, and articles necessarily purchased from local dealers. Usually board and lodging expenses are consid-

ered allowable only when incurred away from headquarters. Receipts should be taken for all expenditures, and attached to the Expense Account when sent to the chief engineer. The receipt stubs serve as a record of expenditures, but it is also desirable to preserve a copy of the Expense Account.

The distribution of Pay Rolls and Expense Accounts is usually required to be indicated, that is, the Construction item to which the expense or labor is to be charged must be classified. The Classification of Expenditures as given by the Inter State Commerce Commi ssion is followed. This classification for the usual subjects with which the resident engineer has to deal are given below.

1.ENGINEERING.-

To this acount should be charged all salaries and expenses of engineers, assistants, and axemen; teams for transportation of engineers and men to and from work, or upon trips of inspection of line of work, or incidental thereto; engineer's instruments, rods, chains, axes, hatchets, tape lines, keel or marking chalk, stakes, profile and drawing paper, tracing linen or paper, cross-section paper, transit and level books, cross-section or topographic books, India ink and colors, drawing boards, stools, map cases, paper racks, stationary for office or field, fuel, lights, and camp equipage, and other analogous items.

2.RIGHT OF WAY AND STATION GROUNDS.-

To this account should be charged the cost of land acquired for roadbed (of necessary width conformably to depth and slopes of excavations and embankments), station and terminal grounds; also the cost of land purchased for ingress or egress to and from station grounds; salaries and expenses of council, right of way agent, and of engineers and assistants when especially engaged upon such matters; stakes used to denote right of way limits; expenses of appraisals, or of juries, commissioners or arbitrators in condemnation cases; cost of removal of buildings upon right of way, station or terminal grounds, but not included in property purchased; stationary supplied right of way agents, engineers, and assistants, engineer's instruments, etc., when used for such purposes; commissions paid outside parties for purchase of properties for these purposes; cost of plats, abstracts, notarial deeds, recording deeds, etc.

Not particularly No. 3, "Real Estate", as regards the cost of property purchased but not required for the operation of the road

3. REAL ESTATE.

To this account should be charged the cost of all land purch - ased by the railway company in excess of that actually required

for roadbed, station or terminal grounds, or other specific purpose, including all expenses incurred in connection with such purpose as enumerated in account No. 2, "Right of Way and Station Grounds." A portion of the cost of land purchased outside right of way for borrow pits or waste banks should be charged to this account.

Note.- The amount to be charged to real eastate should be an estimate of the salable value of said borrow pits or waste banks after completion of the road.

4. GRADING.-

To this account should be charged the cost of grading roadbed, whether excavations or embankments; clearing and grubbing; dressing slopes of cuts and fills; reconstructing pikes or roads; ditching roadbed; berm ditches; cost of material taken from borrow pits, haul if allowed; amounts paid for privelege of making waste banks outside of company's right of way or station grounds; ditches for waterways not specially required by right-of-way agreement, in which case cost would be properly chargeable to account No. 2, "Right of Way and Station Grounds." This account includes retaining walls and other masonry or riprap for the protection of embankments, cuts, and slopes; cribbing or bulkheading built to protect the tracks or embankments along the seashore or banks of lakes and streams, including the cost of the cribs, breakwaters, wing dams, or other devices constructed to change the direction of the current of a stream to prevent the washing of the bank; also freight on material, and transportation and subsistence of grading gangs.

5. TUNNELS.-

To this account should be charged the cost of tunneling, including such timber as may be used for centering, packing, etc.; cost of stone, brick, cement, sand, lime, salt, piles, timber, spikes, nails, braces, concrete, etc., used in the construction or lining of the same; cost of labor preparing or securing the same, transportation, scaffolding, cofferdams, and pneumatic caissons; cost of soundings, and machinery, pumps, engines, etc. used for such work. This account does not include grading or surfacing of the roadbed, or the cost of the track through the tunnel.

6. BRIDGES, TRESTLES, AND CULVERTS.-

To this account should be charged the cost of all bridges and trestles erected to carry tracks over streams, ravines, streets, or other railways, and culverts, both substructure and superstructure, including transportation. This account should include abutments, piers, supports, draw and pier protection,; machinery to operate drawbridges; masonry ends and wing walls for culverts; cost of inspection of bridge material either at shop or site of structure; cost of tests; cost of wing dams, cribs, or ice-breakers for the purpose of regulating the current of a steam or breaking up ice jams before reaching a bridge; also labor and material used in painting structure.

In case "false work" is furnished by the railway company for erection of bridge superstructure, the cost of same should be charged to this account, and then removed, the value of the material removed should be credited to this account and charged to

the account benefited.
7. TIES.
8. RAILS.
9. TRACK FASTENINGS.
10. FROGS AND SWITCHES.
11. BALLAST.
12. TRACK LAYING AND SURFACING.
13. FENCING RIGHT OF WAY.-

To this account should be charged the cost of all material and labor used in constructing board, wire, rail, hedge, stone, or other fences along the right of way ot limits of roadbed, and transportation; but no charge should be made to this account for fences constructed around stock yards, fuel stations, station grounds, shops, and on other properties outside of right of way, which should be charged to their appropriate accounts. The cost of permanent or portable fences for protection of tracks from snow should not be charged to this account, but to account No. 28, "Miscellaneous Structures".

14. CROSSING, CATTLE GUARDS, AND SIGNS.-
15. INTERLOCKING OR SIGNAL APPARATUS.
16. TELEGRAPH LINES.
17. STATION BUILDINGS AND FIXTURES.-

To this account should be charged the cost of all material and labor expended on all station buildings, including cost of transportation, platforms, sidewalks, excavation, foundation, drainage, water, gas, and sewer pipes and connections, steam heating apparatus, stoves, electric light and power fixtures, including wiring for same, grading and putting ground in order after building has been finished; electric bells, elevators, and all other material, furniture, or fixtures used to complete the building; wells for water supply of stations; also salaries and expenses of engineers and architects.

Note.- This account should include the cost of similar buildings on docks, wharves, and piers, when used for station purposes.

18. SHOPS, ROUNDHOUSES, AND TURNTABLES.
19. SHOP MACHINERY AND TOOLS.
20. WATER STATIONS.-

To this account should be charged the cost of material and labor expended in the construction of water stations for the purpose of supplying locomotives with water, including cost of windmills, pumps, boilers, pumphouses, tanks, tubs, tank foundations, track tanks, or troughs, engines and all fixtures and pipes, standpipes, or penstocks and connections; wells, dams, and resevoirs or cisterns; transportation; also engineering expenses, and tools used in the work. This account must not include waterworks, wells, etc., exclusively for supply of stations, hotels, tenements, or section houses, which should be charged to the appropriate accounts.

21. FUEL STATIONS.
22. GRAIN ELEVATORS.
23. STORAGE WAREHOUSES.
24. DOCKS AND WHARVES.
25. ELECTRIC-LIGHT PLANTS.

26. ELECTRO-MOTIVE-POWER PLANTS.
27. GAS-MAKING PLANTS.
28. MISCELLANEOUS STRUCTURES.
29. LEGAL EXPENSES.-
    To this account should be charged the amount of all attorneys' salaries, fees, and expenses, and all other incidental legal expenses incurred during the process of construction of a road, except when the expense can be charged directly to the account for which it was incurred.
30. INTEREST AND DISCOUNT.
31. GENERAL EXPENSES.

REQUISITIONS.- Requisitions for supplies are properly sent in about the first of the month, unless there is good reason for making them at some other time. The resident engineer should suggest to his party the habit of making note during the month of any supplies that may be needed, then there will be little chance of omitting anything, and the number of requisitions will be cut down.

In this connection the inventory, if monthly, will suggest most of the necessary supplies and will reveal material on hand that might have been overlooked and unnecessarily ordered.

The inventory should consist of a list of all company material on hand together with remarks as to its condition.

A separate instrument report is also required by some companies. This will give a statement of the engineering instruments on hand, specifying whether they are in good condition, usable, or worn out.

FINAL ESTIMATE.- The final estimate will generally be entered upon the same form as the monthly estimate but will be marked "Final Estimate." On the Cost sheet no percentage will be retained. The work must have been properly finished and formally accepted before the final estimate is issued.

MATERIAL RECEIVED.- Material received has been partly covered under the heading of "Cars of material received and unloaded." There may be, however, material received by wagon or brought to

the line from local points, such as ties, piles, lumber, stone, cement, gravel, tile, etc., all of which should be carefully checked. The date of receipt and its final disposition together with such other remarks as are pertinent should be recorded. This may be conveniently kept in the same book with cars received and unloaded.

BLANK FORMS

REQUISITION BLANK

X.Y.Z. Ry.

Req. No.__________ Place__________ Date__________

To the Storekeeper at____________________

Ship to__________ at__________ Charge to acct. of__________

Quantity	Article	Classification No.	Weight	Price	Amount

Approved__________ Chief Engr. Signed__________ Res. Engr.

EXPENSE ACCOUNT

X. Y. Z. Ry.

Place__________ Date__________

Necessary expenses incurred in the service of__________ Ry. Month of__________

Date	Place	B	D	S	Extra Meals	Lodging	Livery	R.R. Fare	Sleeper	Teleg.	Miscel.	Total	Remarks

Approved__________ Signed__________

DISTRIBUTION OF TIME

Eng'g Dep't.

Name__________ Rate__________ Month__________ 19____

	Date																															No. of Days	Amount	Kind of Work	A.D.	Charge
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31					
																														Total						

DAILY RECORD OF TIME

Month__________ 19____

Name	Check No.	Occupation	Date — Days of the Month 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 etc. to 31	Total Hours	Rate of Pay per Mo.	per Day	Amount

Note: First name should be written out in full, and middle initial given.

When a man is paid by certificate, "C.G." is written after his name; if he is hired again his name must be entered on the roll again.

Amounts should be calculated and shown to even five (5) or ten (10) cents.

Amounts for fractional months should be calculated upon the basis of the actual number of days in the month; the time worked should include Sundays and holidays.

J.C.P.

CHAPTER XI

DRAWINGS

There are always a great many plans, sketches, diagrams, profiles and maps to be made out and, unless the company sends out special instructions concerning drawings, (which is not common) there may be as many styles and sizes used as there are drawings to be made. Each resident engineer may have his own standard. It is to systematize and standardize this part of the resident engineer's work that the following suggestions are given.

SCALE.- The scale of the drawing must first be fixed upon. If the drawing is of an area, property plat, or building, and it is desirable to scale off distances to the nearest foot, then a scale of 1" = 50' is about as small as can be used consistently. If the drawing is of masonry work or other structural plans, then a scale of 1" = 4' permits of scaling distances to the nearest inch with practical certainty, and a scale of 1" = 2' to the nearest one half inch. A reading glass is helpful if close scaling is desirable.

Tracing cloth shrinks and expands considerably so that scaling from it, or from blue prints made from it, is likely to be unreliable, hence it is always best to put the calculated dimensions down in numerals when it is desired to show accurate distances. On drawings of a scale of 1" = 100' or greater, numerical dimensions of buildings and distances to objects are usually omitted.

The scale chosen must depend largely upon the amount of detail to be shown upon the drawing, the purpose for which it will be used,

the papers which it is to accompany, as deeds, leases, etc., and standard sizes of filing cabinets and blue print frames.

In a general way, it may be stated that a scale of 1' = 1000' is often used for a condensed map showing few, if any, details; 1" = 400' for alinement and right of way maps, where details are unimportant. 1" = 200' is also quite common for these maps. For yard and station plans and city properties a scale of 1" = 100' or 50' is very common; 1" = 40' is also a favorite with some for these plans. For single city lots, buildings, and much detail, 1" = 20' is convenient. Scales of 1" = 20' or 1" = 40' are often convenient since distances can be easily scaled with an architects scale or one graduated to 1/2", 1/4", 1/8", etc. Such a graduation applies equally well to scales of 1" = 200' and 400', since 1/2" = 100' or 200', 1/4" = 50' or 100', 1/8" = 25' or 50' respectively. A common scale for ravine sections is 1" = 10' or 1" = 20'.

A common scale for masonry plans is 1" = 2' or 1" = 4'.

Where land is subdivided according to the government land subdivision, sacles of 1" = 1 mile, 2 miles, or 4 miles, may be found convenient for large tracts, also for drainage areas.

Following is a table of scales showing the actual ratios:

One	inch	equals	2	feet	and the	ratio		1:24
"	"	"	4	"	"	"	"	1:48
"	"	"	10	"	"	"	"	1:120
"	"	"	20	"	"	"	"	1:240
"	"	"	40	"	or	0.0076	miles	1:480
"	"	"	50	"	"	0.0095	"	1:600
"	"	"	100	"	"	0.0190	"	1:1200
"	"	"	200	"	"	0.0380	"	1:2400

One inch equals	400 feet or 0.076 miles		1:4800
" " "	1000 "	" 0.189 "	1:12000
" " "	5280 "	" 1.000 "	1:63360

STANDARD SIZES.- It is a good thing to have a system upon which the standard sizes of drawings is based. Some companies specify the dimensions to be used, others leave the choice and design to the resident engineer.

There are various commercial sizes of drawing paper, each having a trade name. They may vary slightly in dimensions with different kinds of paper, but in general may be considered as following the sizes given below.

Cap.	13"x17"	Sup. Royal	19 x 27	Antiquarian	31 x 52 (or 53).
Demy	15 x 20	Imperial	22 (or 21) x 30		
Medium	17 x 22	Atlas	26 x 34		
Royal	19 x 24	Double Elephant	26(or 27) x 40.		

Roll paper comes in the following widths: 24, 27, 30, 36, 42, 54, 58, and 62 inches. The scheme followed in systematizing drawings may be illustrated as follows: Double Elephant size, 26 x 40, cuts to 20 x 26, 13 x 20, 10 x 13; a sheet 24 x 36 cuts to 18 x 24, 12 x 18, 9 x 12, etc.

Sheets are also cut to correspondence paper dimensions, 8 1/2x11.

BORDERS.- To give the drawing a finished appearance a border line should be drawn from 1/2" to 1" from the edge of the paper, preferably one inch. If the sheets are to be bound then more margin should be left on the binding edge.

It is generally considered good form to make a heavy border line, say 1/20 inch, on light line drawings, and a light border line on heavy line drawings. Drawings should not crowd the border line. It

is well to count on leaving at least one inch inside of the border free of lines, particularly in the case of structural plans. In these plans it may also be well to work from the edges of the paper, or one inch inside of the border line, toward the center of the sheet unless it is known definitely what shape and positions the elevations and plans will assume.

TITLES.- The writer considers the lower right hand corner of the sheet the proper place for the title if it is possible to so locate it. The size of the title should be varied to be consistent with the dimensions ofthe sheet. Some engineers specify a title not greater than 6" x 8" or 6" by 10". The writer recommends that the sides including the rectangle be one fourth the length of the respective parallel borders.

The most important words should be emphasized by making them largest. The largest letters in the title should not be higher than 1.5% of the length of the shortest border line. In general, the drawing will look better if one style of letter, either slanting or vertical, is used throughout. Vertical letters are often given preference for headings, names and titles, and slanting letters for notes, explanations, etc.

LETTERS.- The following proportions give well designed letters, based on 6 units in height: I = 1; J = 4; L = 4 or 4.5; F, N, P, U, H = 4.5; B, E, R, S, = 4.75; D, T, V, Z, C, G, O, Q = 5; A, K, X, Y = 5.5; M = 6; W = 7.

Slanting letters slope 2:6. Stems are all one unit wide. Space letters to give uniform shading. Space words not less than four units apart.

Explanatory notes may be printed in capitals or small letters.

On large drawings capital letters 0.1" high look well, or small letters with lower case 3/50" and upper case 5/50" (1/10") high. Plainer and neater small letters are obtained if they are slanted and made narrow. In general, the small letters are adapted to small drawings and capital letters to the larger ones.

Plain Gothic letters for working plans and drawings are advisable, with no attempt at ornamentation. Neat Roman letters are graceful and artistic and well adapted to maps. They must, however, be drawn with care, particular attention being paid to the proportions and to the uniformity of hair lines and serifs, otherwise they will fall far short of the artistic.

HINTS FOR THE DRAFTSMAN.- In general, an attempt should be made to show all outlines and detail very accurately. To this end the pencil should be a 5H or 6H for masonry plans, etc., and an 8H may be serviceable for small scale maps. The pencil must be kept sharp. With an accurately drawn map dimensions may be closely checked by scale. On the tracing and consequently on the blue print the lines may be made coarser. The idea is to strive toward an ideal drawing on the detail paper, for the subsequent changes and manipulations will destroy much of the accuracy. Try to plot points to the nearest 0.01 of an inch.

Where several lines terminate at the same point, it is usually better, particularly in inking, to draw the lines <u>away</u> from the point. Where arcs and connecting tangents are to be drawn, the best results are obtained if the former are drawn first. In general, left hand and top lines on the drawing should be inked first, that is, inking should proceed downward and from left to right. Dimension lines should be hair lines or fine dotted lines with

distinct arrow points at the ends. Use scale rather than compass or dividers for laying off distances except on arcs or curves.

PENS.- Proper sizes of pens are essential to neat work. For ordinary lines pens of the Gillette 303 and 404 type are satisfactory; for heavy lines and letters, large falcon, Crawford's Old Reliable, and Leonard's Ball Pointed, types are good; while for mapping, the crowquill and special mapping pens are most satisfactory.

ORIENTATION OF DRAWINGS.- Whenever possible north should be kept at the top of the map. It is convenient and productive of system to have the plans and elevations of working drawings always placed in the same relative positions whenever possible. For example, in masonry drawings of piers, culverts, etc., the writer suggests the lower left corner for the plan of the structure, the upper left corner for the side elevation, the upper right corner for the front elevation or cross section, and the lower right corner for the title, bill of material, explanatory notes, etc.

In lettering along lines parallel with the end borders, the words should be written upward and to the left of the line; for lines sloping from the bottom upward toward the right the words should be written upward and above the line; for those sloping from the top downward toward the right the words should be written downward and above the line.

When a railway survey is run from west to east the north will be at the top of the map. The corresponding profile should be plotted from left to right. When the line is surveyed from east to west the north should be toward the top of the map but the profile plotted from right to left. If the general direction of the survey is north and south and it is desirable to plot along the long axis of

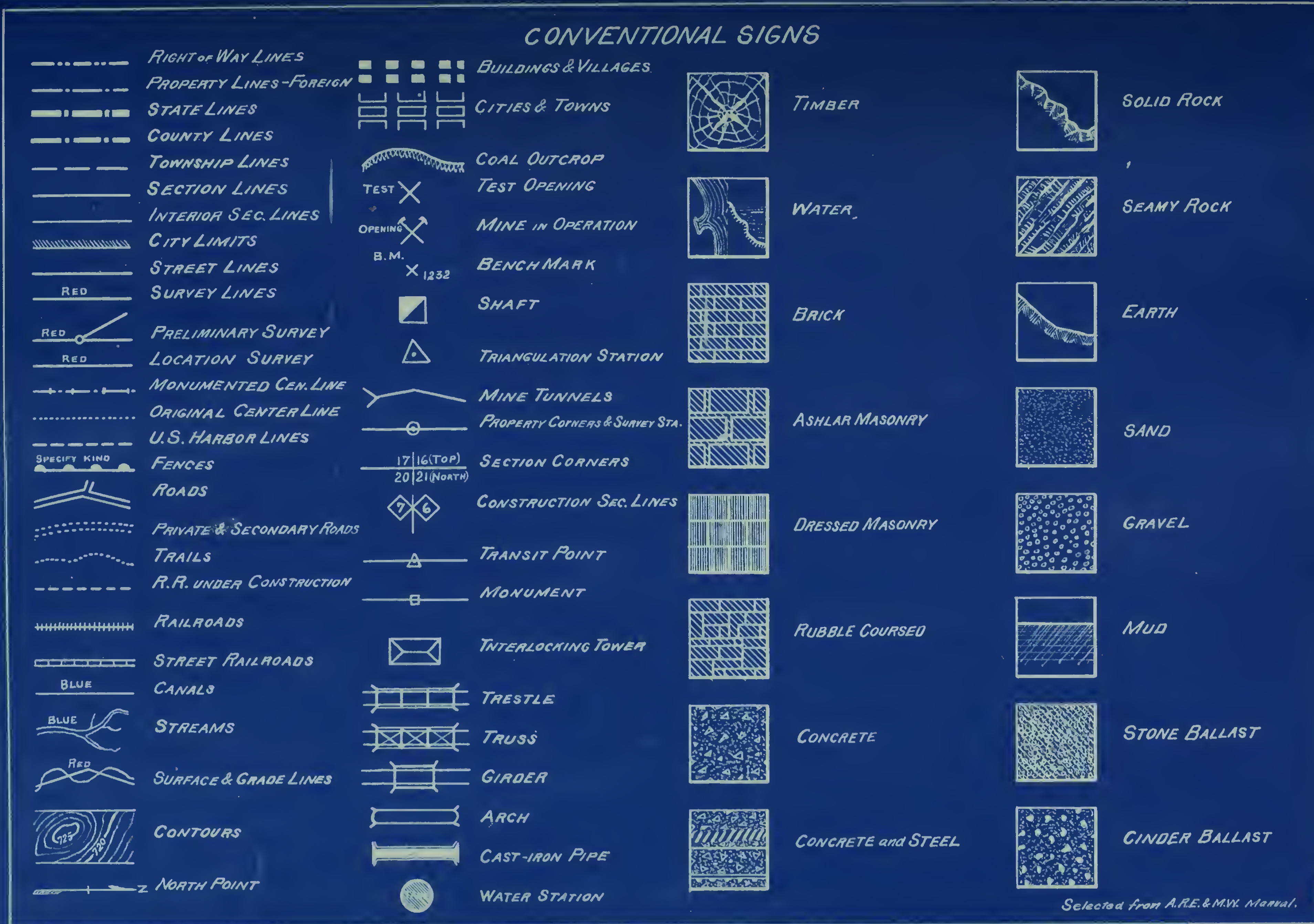
the drawing sheet, then the writer prefers to make the left end of the sheet north and the top east, with the corresponding profiles plotted in the same direction as the survey is plotted, that is, if the survey runs from north to south, the profile will be plotted from left to right; if it runs from south to north, then the profile will be plotted from right to left. The north point or meridian should always be shown in a conspicuous place, and magnetic declination indicated.

CONVENTIONAL SIGNS.- See plate.

PLOTTING

Latitudes and Departures.- For areas surveyed by metes and bounds, that is, by distances and bearings, plotting by latitudes and departures is most satisfactory as it gives a good check upon the calculations and is easily applied with tee-square and triangles since all lines are parallel to, or at right angles with, each other. The greatest objection is the time taken in calculating the latitudes and departures. If tables are at hand this is not laborious, and if the areas of the surveys are to be determined, they are generally calculated by latitudes and departures, in which case no extra time has been consumed in getting the plotting data. The latitude of a line equals the length multiplied by the cosine of its bearing, and the departure equals the length multiplied by the sine of its bearing. All plotting co-ordinates are thus measured along east and west, or north and south lines.

Tangent Method.- The tangent method is often most convenient for laying off angles. An example will best illustrate.
The angle to be laid off is 41°-10'. The natural tangent is .8744 or $\frac{8744}{10000}$. Laying off 100 units to some convenient scale (the larger



Selected from A.R.E.&M.W. Manual.

the distance the more accurate) along the given line from the vertex of the angle, then 87 of the same units at right angles to the given line, a point is located. A line connecting the vertex with this point makes an angle of 41°-10' with the given line. Natural sines and cosines may be used but natural tangents are more generally adapted. By using a large scale this method may be made more reliable than the protractor. The 100 unit distance corresponds to the radius of the protractor. The protractor is often difficult to center precisely, slides easily, and unless very large in diameter, is recommended only for rough plotting. Natural tangents may be looked up and applied about as quickly as a protractor can be accurately oriented and set. It should not be used for fixing the direction of lines that are much longer than the radius of the protractor.

The following table will serve to show the degree of accuracy to which plotting by tangents or protractor may be consistently carried.

It is assumed that points are plotted to the nearest 1/100 of an inch, which may be accomplished with reasonable care, then on a scale with the inches divided into fiftieths the draftsman would estimate to the nearest half of one fiftieth of an inch. 100 divisions (or fiftieths) equal 2 inches which would be equivelant to a 4" protractor. Since the points can be located only to 1/100 of an inch then it is consistent to use only the first two decimals of the natural tangent.

ACCURACY OBTAINED BY TANGENT METHOD

Scale Divided	100 Divisions Equals	Diam. of Equivalent Protractor	The Plotted Point is Located to the Nearest	Look up Nat. Tangent to the nearest	Accuracy, in minutes of arc, with which the point may be plotted. 0° to 10°	20°	30°	40°	45°
$\frac{1}{50}$ inch	2 inches	4 inches	$\frac{1}{2}$ of $\frac{1}{50}$ inch or $\frac{1}{200}$ of 100 division	0.005	$16\frac{1}{3}$	15	$13\frac{1}{5}$	10	$8\frac{1}{2}$
$\frac{1}{40}$ "	$2\frac{1}{2}$ "	5 "	$\frac{2}{5}$ " $\frac{1}{40}$ " " $\frac{1}{250}$ " " "	0.004	$13\frac{1}{3}$	12	$10\frac{1}{2}$	8	7
$\frac{1}{30}$ "	$3\frac{1}{3}$ "	$6\frac{2}{3}$ "	$\frac{1}{3}$ " $\frac{1}{30}$ " " $\frac{1}{333}$ " " "	0.003	10	9	8	6	5
$\frac{1}{20}$ "	5 "	10 "	$\frac{1}{5}$ " $\frac{1}{20}$ " " $\frac{1}{500}$ " " "	0.002	7	6	5	4	$3\frac{1}{2}$
$\frac{1}{10}$ "	10 "	20 "	$\frac{1}{10}$ " $\frac{1}{10}$ " " $\frac{1}{1000}$ " " "	0.001	3	3	$2\frac{1}{2}$	2	$1\frac{2}{3}$

From this table it is seen that using 100 divisions along a 5" scale we would probably use the 20th scale and estimate to 1/5 of 1/20th division or to 1/100", which is equivalent to 1/500 of the length used (for laying off the radius). It would then be consistent to look up the natural tangent, so far as plotting is concerned, to the nearest 0.002, which would permit of plotting to the nearest 7 minutes of arc for angles up to about 10°, to the nearest 6' near 20°, 5' near 30°, 4' near 40° and about 3 1/2' near 45°.

ALINEMENT PLANS.- These plans should show the alinement of survey giving the degree of curve, central angle, the P.C., P.T., and P.I., and if curves are spiraled, the P.S., and P.C.C., rate of spiral, and spiral offset.

Show radii at P.C. and P.T., also subtangents, with fine dotted lines. All culture and topography should be indicated, also plusses and distances, buildings, highways, street and steam railways, all property lines, section, township, and range, lines. Tie lines to section corners and property lines should be carefully noted by numerals. In general, all important distances used for "ties" should be indicated by numerals and dimension lines. At least every tenth station, beginning at zero, should be indicated by short transverse lines and numbered to right of line, unless numbers thus placed are upside down. The scale may be chosen as convenience and purpose may

dictate. Preliminary lines and proposed lines are often shown in red ink; location lines in black.

RIGHT OF WAY MAPS.- Right of way maps may embrace a good many of the features shown in the Alinement Plans, particularly the subdivision of land into townships, sections, etc., together with the tie lines. The company right of way is usually outlined by distinct lines shaded with colors to attract attention readily. They are made to various scales as indicated under "Drawings in General."

PROPERTY PLATS.- These plats consist of drawings of separate parcels of land leased or purchased by the company. They are usually made to show the metes and bounds of the property, or the description that is followed in the lease or deed. The length of all lines should be noted by distinct numerals, and the adjusted and calculated bearings with respect to true meridians also shown. A north point, and a title giving the railway company and other parties concerned in the transfer, the date and certification of the engineer, and other pertinent notes, may be added. The scale is chosen so that the plat can be made of such size as to be conveniently attached to, and filed with, the lease or deed.

PROFILES.- Profiles are generally plotted upon Plate A profile paper to a scale of 1" = 400' horizontally and 1" = 20' vertically. Plate B profile paper is sometimes used where a more condensed profile is desired. It is ruled in 4 divisions to the inch measured horizontally and 30 divisions vertically. The profile should contain the ground line, grade line, and rate per cent, with the elevation of grade at every station shown on vertical curves. All waterways with proposed structures should be noted, and such culture as timber, clearings, and cultivated land; also cubic yards of material in

cuts and fills, creek diversions, channels, etc. The alinement should be shown in a conventional way, with road crossings, fences, section, and township lines oriented with respect to the line as nearly as possible, and all plusses shown. Every tenth station should be shown at the bottom, and also at the top, of the sheet. The construction sections, or miles, should be defined by conventional mile post signs properly numbered. The elevation datum should be repeated at least every 100 stations for convenience in following elevations.

The alinement is best placed near the bottom of the sheet, the ground line near the center, the culture and mile posts near the top. Grade line elevations are shown in red, other features in black

PROFILES AND CROSS SECTIONS OF RAVINE SECTIONS.- These are shown in various ways. Frequently an accurate contour map is made with a contour interval of one foot on gentle slopes or perhaps 5 feet on rugged slopes. The more common form is the profile or cross section sheet. Cross sections are taken with respect to the center line at regular intervals, say every ten feet, or oftener if the ground warrants it, or sometimes at every trestle bent if a trestle is to be used and if it can be reasonably well ascertained beforehand about where the bents will be located. Transverse profiles may then be plotted from these cross sections. Profiles parallel to the center line and 10 to 20 feet therefrom are most conveniently obtained by running the lines in with the transit, then taking elevations along them as along the center line.

When the profiles are plotted, the one at the center line is shown as a full line while those at the sides are dotted or shown in colors. Care must be taken to distinguish right from left by

by conventional lines.

CREEK DIVERSIONS.- Separate profiles should be made of creek diversions on a sheet, with a plan ~~to~~ showing the exact location with reference to the railway center line. The profile and cross section will be treated as ordinary cuts, and are of assistance in calculating and for reference.

CHAPTER XIII

FINISHING THE WORK

The specifications furnish the information as to how the work should be performed. Some suggestions concerning the checking of the work and the precision required may be useful. Finishing work is comparatively expensive to the contractor and, although this is taken into account in the contract price, there is often an inclination, in spite of plans and specifications, to do only that in which there is most profit, and no more of the "finishing" work than the engineer will demand.

In clearing and grubbing, the brush and rubbish should be burned and logs piled at once. There is little excuse for allowing brush piles, though green, to stand for months always in the way of surveys, and making it necessary to withhold a part of the estimate. A complete estimate should not be turned in for ground littered with logs and brush piles. They will burn if properly fired and it is usually economy in the end for both contractor and engineer to finish clearing the ground as the work proceeds.

Stumps and trees if not to be grubbed should be cut low, not over a foot above the ground, and frequently may be sawed flush with the ground. The tendency is to cut them so high that the chopper need not bend his back.

In cuts and borrow pits the sloped surfaces should be true planes and not convex surfaces and the intersection of slope with ground line should be straight, or properly curved, lines, not jag-

ged ones. If borrow pits inside the right of way must be varied in width, the side next to the roadbed should be neatly lined. Any projecting stones in cuts should be removed.

The ditches in cuts should be full size and trued to standard section and the grade of the bottom made to conform to the sub-grade line, or made to drain properly.

As guides for finishing the roadbed grade stakes should be set at least every 100 feet on the tangents. On curves they should be set every 50 feet up to 10°, and every 25 feet onsharper curves. The stakes are set one half the width of roadbed out on both sides of the centerline, driven down until the top is at the elevation of sub-grade and then keeled on top with blue keel to distinguish them as grade stakes. If the roadbed is to be crowned at the center, a center grade stake should be set to indicate the rise of the crown.

On curves where the superelevation is given by elevating the roadbed on the outside of the curve and depressing it on the inside, finishing stakes must be set accordingly. If the superelevation is all obtained by raising the outer rail, as is customary in the U. S., then the line of the roadbed underneath the inner rail will be the grade line as given by the profile. The outer shoulder of the roadbed will then be raised above the grade line more than the inner one is depressed below it.

The embankment should be built to the full prismoid as staked out. The tendency is often to make it concave between the grade stakes, both vertically and horizontally, as indicated in the sketch. The crown of the roadbed should be symetrical with respect to the centerline; if too wide it

should be spaded to the proper shoulder line.

If shrinkage is to be allowed, the top of the grade stake will mark a certain percentage of the center height of the fill above the grade line.

(See discussion of Shrinkage and Swell, page 118.).

Where the embankment can be allowed to stand several months before the track is laid, the stated shrinkage may be allowed for, but if the track is to be laid at once this would be objectionable since a very rough and rolling grade line might result where the center height varied considerably. The approaches to bridges might be higher than the top of stringers and leave no room for ballast, or make a bad run off at the end of the bridge. In such an event it would be better to assume a normal shrinkage and make the grade line with shrinkage added as uniform a line as consistent.

Bridge and masonry work is done under inspection either by an inspector or by the engineer himself and there is less likelihood of imperfections or unfinished work. The materials entering into the structure are often inspected and approved before they are brought to the site, or before using.

Accepting the Work.- The resident engineer should not accept any work as completed unless authorized to do so by the chief engineer. He should, however, make a report of the completion of the work as early as consistent so that if desirable the work may be accepted without undue delay to the contractor.

Approximate or monthly estimates should not be accepted as "finals" unless they have been taken up as final estimates.

Companies sometimes specify that possession of a piece of un-

finished work by the company shall not constitute an acceptance of of the work nor relieve the contractor from finishing it.

Track Centers.- Track centers should be set every 100 feet on tangents and every 50 feet on simple curves, and every chord length on spirals. The stakes should be firmly set and allowed to project six or eight inches above the subgrade. They are likely to be disturbed if they project much above the top of the ties. Tacks should be set to mark exact centers.

Where center stakes are to be used for track laying only, almost any small stakes or pegs will suffice. It is usually poor economy to set regular track centers marked with tacks for this preliminary track work since they are very likely to be disturbed by the track gang.

Ballast Stakes.- After the track is laid, then ballast stakes may be set. It is well not to set these stakes a long time before they will be used since they are in constant danger of being disturbed or destroyed. They should be set, however, before the ballast is distributed, otherwise it will be difficult to locate and drive them. The top of the stake is driven to the grade line, usually the elevation of top of rail. Any other grade line may be used such as base of rail, top of ballast, etc., but the trackmen must be informed accordingly.

The stakes are set from 5 to 7 feet from the center line, or may mark the toe of the ballast slope. It is sufficient to set a row of stakes on only one side of the track by measuring out from the track centers. They are set on the inside of curves, elevations being referred to the grade line of the inside rail.

CHAPTER XIV

HANDLING GRADE MATERIALS

LOOSENING.- Earth is usually loosened by steam shovel, plow, pick or shovel. Plowing is the usual method particularly on large pieces of work other than steam shovel work since it is the cheapest.

Plowing.- From Gillette's Earthwork And Its Cost.-

1 2 horse team, 2 men, 1 plow, 25 cu. yd. fairly tough clay per hr.
1 " " ", 2 ", 1 ", 35 " " gravel and loam " "
4 or 6 horses, 4-6 ", 1 pick pointed plow, 15-20 cu.yd. tough clay.

From Morris:-

1 team, 2 men, 20 to 30 cu. yd. stong heavy soil per hour.
1 ", 2 ", 40 to 60 " " ordinary loam.

Picking.- Trautwine:-

1.4	cu.	yd.	stiff clay or cemented gravel	per	man	per	hour.
2.5	"	"	strong heavy soils	"	"	"	".
4.0	"	"	loam	"	"	"	".
6.0	"	"	light sandy soil	"	"	"	".
20.0	"	"	fine sand	"	"	"	".

Shoveling into Wagons or other Conveyances.-

Ancelin:-

0.8 cu. yd. per man per hour, of mud into wheelbarrows.
1.7 to 2.7 cu. yd. per man per hour, gravel into wheebarrows.
1.6 to 4.8 cu. yd. " " " "- earth " " "
Cole:- 1 cu. yd. " " " "- all kinds earth into wagons.

Gillette:-	1.8 cu. yd. per man per hr.	- sand into cars from a high face.
"	1.3 " " " " " "	- gravelly soil into wagons after plowing.
Morris:-	1.0 " " " " " "	- clay and gravel into carts.
"	1.2 " " " " " "	- loam into carts.
"	1.4 " " " " " "	- sandy earth into carts.
Parker:-	2.0 " " " " " "	- loose sand into carts.

Picking and Shoveling.-

Ancelin:-	0.4 cu. yd. per man per hr.	- hardpan (clay and gravel).
"	0.8 to 1.2 " " " " " "	- common earth.
Cole:-	0.33 " " " " " "	- hardpan.
"	.85 " " " " " "	- stiff clay.
"	1.00 " " " " " "	- clay.
"	1.25 " " " " " "	- sand.
Gillette:-		
	0.8 to 1.2 " " " " " "	- sandy soil.
"	1.3 " " " " " "	- clayey earth.
"	0.9 " " " " " "	- clay, fairly tough.
"	0.75 " " " " " "	- sandy earth, frozen.
Billings:-		
	0.7 to 0.8 " " " " " "	- gravel or clay.
Hodgson:-		
	1.1 to 1.2 " " " " " "	- earth.

At 15¢ per hour the cost of excavating with pick and loading is as follows: hardpan 40¢, tough clay 20¢, ordinary clay, gravel, or loam 15¢, light sandy soils 12¢ per cubic yards.

LOOSE ROCK.- This being a material which is defined with so much uncertainty and in so many different ways, it will not be attempted here to give any data concerning it. It may be plowed, or picked

or worked with steam shovel, and is frequently blasted to facilitate handling.

SOLID ROCK.- Solid rock may be broken up in various ways: using plug and feathers, heating it, blasting, etc. With the advent of the modern steam or air drill, blasting is by far the most rapid and economical way of loosening up large quantities.

Drilling the holes for the explosives may cost from 10¢ to 20¢ per foot, depending upon kind of rock, bedding of rock, depth of excavation, size and kind of drill, plant, price of labor, etc. The length of the drill hole necessary, per cubic yard of rock, varies with the depth of cut, or face to which the rock is to be excavated. It is common to space the holes a distance apart equal to the depth of the hole. Gillette gives a formula which gives somewhat different results. If S = spacing of holes, and d = depth, then $S = 2.5\sqrt{d}$, the author claiming that although S = d is good practise for igneous rock, $S = 2.5\sqrt{d}$ is better for limestone, sandstone, etc.

From Gillette's Economics of Road Construction:

Depth "d" in feet.	Feet of drill hole per cubic yard of rock.	
	$S = 2.5\sqrt{d}$	S = d
2	2.2	1.0
4	1.1	1.7
6	0.72	0.75
8	0.55	0.40
12	0.36	0.20

The cost is seen to decrease proportionately as the depth of the hole increases. Holes from 6 feet to 12 feet in depth will gener-

ally give economical results. The amount of explosive necessary is given by Gillette as P = 3/d where P = pounds of 40% dynamite per cubic yard of rock, and d = depth of hole.

Byrne gives $P = cl^3$, where P = pounds of explosive per cubic yard, l = length in feet of line of least resistance, c = 0.032 for B.P. powder, and 0.003 for dynamite.

Table from Gillette.

40% dynamite @ 15¢, drilling 15¢ per foot.

d in feet	1	2	3	4	6	8	10	12
Cost of dynamite per cu. yd.	26	18	15	13	11	9	8	7
" " drilling " " "	66	32	22	17	10	9	7	6
Total cost	92	50	37	30	21	18	15	13

The cost of sledging the larger blasted pieces and throwing them back from the face, to be loaded, may be 15¢ or 20¢ per cubic yard.

HAULING

It is at least difficult and perhaps impossible to give close estimates on the cost of hauling earth or rock.

The following general rules formulated by Gillette in "Earthwork and Its Cost" will give the engineer good general conceptions concerning this subject.

WHEELBARROWS.- Capacity 1/15 cubic yard.

Rule 1. To find the cost per cubic yard of picking, shoveling, and hauling average earth in wheebarrows, multiply the wages of a laborer per hour by 7/6 and add 1/3 of an hour's wages for each 100 foot haul. When wages are 15¢ per hour this rule becomes: To a fixed cost of 17 1/2¢ add 5¢ for each 100 feet hauled.

CARTS.- One horse, two wheeled dump carts. Average load 1/3 cu. yd.

Rule II. To find the cost per cubic yard of plowing, shoveling, and hauling "average earth" with carts, add together these items:

1/20 hour's wages of team and driver and helper on plow (2 horses and 2 men).

2/3 " " " laborer shoveling (1 man).

1/4 " " " cart horse and driver for "lost time". (1 horse and 1 man).

To which add 1/20 hour's wages of cart horse and driver for each 100 feet of haul. With wages of a man at 15¢ per hour, this rule becomes: To a fixed cost of 18¢ add 1 1/4¢ per cubic yard per 100 feet of haul.

WAGONS.- Rule III.- To find the cost per cubic yard of average earth moved in 3/4 cu. yd. wagons, add the following items.

1/20 hr's wages of team with driver and helper plowing.

2/3 " " " laborer shoveling.

1/7 " " " team with driver, "lost time".

1/15 " " " laborer dumping wagons.

To this add 1/50 hour's wages of team and driver for each 100 feet hauled.

With wages of men at 15¢ and team and driver 35¢ per hour this rule becomes: To a fixed cost of 18¢, add 0.7¢ per cubic yard for each 100 feet of haul over soft earth roads with steep ascents; or 0.4¢ per cubic yard for each 100 feet haul over hard level earth roads where wagons holding 1.3 cubic yards can be used.

DRAG SCRAPERS.- ("Slips" or "Slussers"). Capacity tough clay 1/10 cu. yd., gravel 1/7 cu. yd., loam 1/5 cu. yd.

Rule IV.- To find the cost per cubic yard of average earth moved with drag scrapers, add together the following items:

1/20 hr's wages of team with driver and plowman for plowing.

1/10 " " " " " " " " for "lost time" load'g.

1/20 hr's wages of laborer loading scrapers.

1/9 " " " team and driver for each 100' haul, assuming no haul ever less than 75 ft. to allow for turning and maneuvering teams.

With wages of men at 15¢ and team and driver 35¢ per hour this rule becomes: To a fixed cost of 6¢ per cubic yard add 4¢ for each 100' haul, assuming no haul ever less than 75 feet. Fairly tough clay, hard to load will cost 1/3 more.

WHEEL SCRAPERS.- The average load of a No. 1 wheeler is 0.2 cu. yd. measured in place, No. 2 = 0.25 cu. yd., No. 2 1/2 = 0.33 cu. yd., No. 3 = 0.4 cu. yd.

	Rule V	Rule VI	Rule VII.
Wheelers used	No. 1	No. 2	No. 3
	hr.	hr.	hr.
Time for plow-team and driver.	1/20	1/20	1/20
" " " " " " "lost time".	1/12	1/15	1/15
" " man loading scraper.	1/15	1/15	1/10
" " man dumping scrapers.		1/15	1/20
" " snatch team and driver.			1/18
" " team and driver for each 100' haul.	1/13	1/16	1/30

No haul less than 75 ft. for No. 1 and No. 2 wheelers.

" " " " 100 ft. for No. 3 wheelers.

Use snatch team with No.2 and No. 3. The material considered is average earth.

If snatch team is used with No. 2 wheelers, add 2¢ per cu. yd.

ELEVATING GRADERS.- Rule VIII.- To find the cost per cubic yard of average earth loaded with an elevating grader and hauled with 3-horse dump wagons, add the following:

1/10 hr's wages of a 2-horse team with driver for loading.

1/9 hr's wages of a 3-horse team with driver for "lost time".
1/10 " " " " man dumping.
Add 1/80 hr's wages of a 3-horse team with driver for each 100 ft. of haul over 500 ft. (3-horse team and driver 45¢ per hour.)

STEAM SHOVEL.- For loading average earth - labor and fuel 5.4¢; interest, repairs and depreciation 3¢; total 8.4¢ per cu. yd.

CARS.- Rule IX.- To find the cost per cu. yd. of loading and moving average earth with cars and horses (working at a face), add these items:

1 hr's wage of laborer undermining and shoveling.
1/30 " " " team with driver "lost time".
1/3 " " " man on dump,- dumping, making trestle, and track shifting. Then add 1/330 hr's wage of team and driver for each 100 ft. haul,- never less than 1000 ft. haul.

To a fixed cost of 16¢, add 0.1¢ per cu. yd. for 100 ft. of haul making the cost of hauling never less than 1¢; and add the cost of materials for the dumping trestle plus $250.00 per mile of track, divided by the total number of cu. yd. moved over the track before it is torn up.

Even though it is impossible to lay down unvarying, general rules giving the cost of handling material unless all the conditions are known, the results obtained by the foregoing rules will warrant reasonable conclusions. Comparative results are better shown than absolute results, perhaps. The following summary will make the advantage of the rules clearer. It should be remembered also that the following items are not included: Foreman, timekeeper, blacksmith, watchman, water boy, interest, rental, insurance, grubbing, spreading, trimming, rolling and sprinkling.

CHAPTER XV

GENERAL CONTRACT PRICES

It is impossible to give contract prices that will serve for use in specific cases. The following are intended only to give a general conception of the prices of work usually performed upon the residency. They are also used in the table of Consistent Measurements and Calculations in the following chapter.

In the absence of specific information, the cost of labor is frequently assumed to be equal to the cost of materials in making estimates.

Engineering and Superintendence is variously estimated from 3% to 10% of the total cost of all other items.

Contingencies may be estimated from 10% to 50%.

Profits to be allowed are about 10% of the actual estimate.

Clearing	$30.00	to	$40.00	per acre
"	8.00	"	12.00	" square.
Grubbing	.50	"	1.00	" square rod.
"	10.00	"	15.00	" square.
Earth excavation	.20	"	.30	" cubic yard.
Loose rock "	.30	"	.50	" " " .
Solid rock "	.80	"	1.00	" " " .
Wet "	1.00	"	2.00	" " " .
Dry masonry	3.00	"	5.00	" " " .
Culvert paving		"	2.00	" " " .
First class stone masonry	15.00	"	20.00	" " " .

Second class stone masonry	$ 7.00 to	10.00	per cubic yard.
Third " " "	5.00 "	7.00	" " " .
Portland cement concrete	5.00 "	10.00	" " " .
Brick work		20.00	" thousand .
Trestle timber	40.00 "	60.00	" 1000 feet B.M.
Foundation piles	.30 "	.40	" lineal foot.
Bridge piles in place	.20 "	.40	" lineal foot.
"Cut off" of piles	.05 "	.10	" lineal feet.
Pile trestles complete	7.00 "	10.00	" lineal feet.

Wooden trestles $10.00 per lineal foot for trestles up to 15 feet high, then add about 25¢ per lineal foot for each additional foot in height.

Cast iron in place	$0.03	per pound.
Wrought " " "	.04	" " .
Steel in bridges	.035 to .04	" " .
Erecting steel bridges	12.00 to 15.00	" ton.
Decking bridges	2.50 to 3.00	" lineal foot.
Cast iron pipe		
Fencing	150.00 to 175.00	per mile of single line.
Cattle guards	25.00	
Road crossing	25.00	
Telegraph	50.00	per mile for labor.
Rail	28.00	per ton.
Rail joints	.018	per pound.
Track bolts	.028	" " .
Track spikes	.020	" " .
Offset splices	2.50	" pair.
Rail braces	.10	each

Nut locks $5.00 per 1000

#10 Split switch complete, as follows:

	85 pound	70 pound	60 pound
Split switch	$25.00	$21.50	$19.50
Connecting rod	1.50	1.50	1.50
Switch stand(high banner)	13.00	13.00	13.00
" Lamp	4.50	4.50	4.50
" lock	.40	.40	.40
Spring rail frog	37.00	32.00	
Rigid frog			19.00
Guard rails	14.00	13.00	8.00
Switch ties	30.00	30.00	30.00
Rail braces	1.50	1.40	1.30
Total	126.90	117.30	97.20

Labor of putting in switch $25.00

CHAPTER XVI

CONSISTENT LIMITS OF ACCURACY

Although precision is a thing to be striven for in engineering work there are instances where refinements in measuring or calculating may be a gross waste of time. The engineer who performs his work with consistent accuracy, attaining a refinement commensurate with its performance will excell in rapidity and economy. The suggestions offered in this chapter will assist the engineer in determining the proper relation of instrumental or field work to the calculated results.

PROBABLE ERROR.- The probable error is an error of such value that the chances are even that the number of errors greater than the probable error is the same as the number of errors less than the probable error. The formula for finding the probable error is as follows:

$E = 0.6745\sqrt{\frac{\Sigma V^2}{n - 1}}$ and $E_m = 0.6745\sqrt{\frac{\Sigma V^2}{n(n - 1)}}$.

n = number of observations or readings.

V = difference between any one observation and the mean of all the observations.

Σ = the sum of, or summation.

E = the probable error of any one observation of the series taken.

E_m= the probable error of the mean of the series of observations.

CHAINING.- Poor chaining and good chaining may be compared by comparing the "chaining ratio" of each. The "chaining ratio" is the difference between two measurements of a line divided by the length

of the line. For good chaining the following ratios are given. In the column headed "Dif" is given the actual difference obtained in chaining a line 1000 feet long twice, at average speed, using plumb bob and chaining pins.

	Dif.	Distance	Ratio	E	E_m
With chain	0.40	1000.00	$\frac{1}{2500}$	$\frac{1}{5000}$	$\frac{1}{7500}$
Steel tape	0.08	1000.00	$\frac{1}{12500}$	$\frac{1}{25000}$	$\frac{1}{37500}$

If the distances are measured only to the nearest 0.1 foot, it is well to know the effect of a sloping chain. A distance of 100 feet measured along a slope of 2°-34' (4.48 feet fall in 100) gives a horizontal distance of 99.9 feet; and a distance of 50 feet measured along a slope of 3°-37.5' (3.16 feet fall in 100) gives a horizontal distance of 49.9 feet. These figures are convenient to refer to in connection with measuring out distances for R. of W. stakes where it is desirable to know the effect in distance of a deviation from a line at right angles to the center line.

The following table gives a list of the factors which will introduce an error of 0.01 foot in 100 feet.

100 foot steel tape:-

If one end is held 1.4 feet higher than the other end the horizontal distance is 99.99 feet.

If the center of the tape is 0.7 foot out of line the horizontal distance is 99.99 feet.

If one end is on line, the other 1.4 feet off line the horizontal distance is 99.99 feet.

If the sag at the middle is 0.6 foot the horizontal distance is 99.99 feet.

If the temperature rises 15° degrees the horizontal distance is

100.01 feet.

If a pull of 15 pounds is used the horizontal distance is 100.01 feet.

LEVEL.- The permissable error for a good engineer's level, when a target is used and the maximum sights are about 300 feet long, is given by the formula $E_p = 0.'05\sqrt{\text{number of miles}}$ or $E_p = 0.007\sqrt{\text{No. Sta.}}$ For rough checking $E_p = 0.'02\sqrt{\text{No. of set-ups}}$, may be used.

The following table gives the error introduced in a 100 foot sight by the bubble being 0.1 inch off center, for bubble tubes ground to various radii.

Radius	Seconds of arc per inch of tube	Error in 100' for 0.1" off center
20	859	0.0417
30	573	0.0278
40	430	0.0208
50	344	0.0167
60	287	0.0139
70	246	0.0119
80	215	0.0104
90	191	0.0093
100	172	0.0083
110	156	0.0076
120	143	0.0069
130	132	0.0064

The approximate correction in feet for Curvature of the Earth and Refraction combined is $0.574(\text{miles})^2$.

COMPASS.-If the needle on the ordinary transit has a sharp point and is in good condition it is possible to read bearings to the nearest 10 minutes of arc or somewhat less, by estimation. The probable error then in measuring the angles of a polygon is $E_p = 5\text{minutes}\sqrt{N}$ where N = the number of sides or the number of set ups of the instrument.

Thus for a four sided field, $E_p = 5\sqrt{4} = 10$ minutes of arc.

TRANSIT.- The usual railroad engineer's transit reads to single

minutes. The probable error of a reading is then about 30 seconds of arc. Then the permissable error, $E_p = 30 \text{ sec.}\sqrt{N}$ in seconds of arc or $E_p = 1/2\sqrt{N}$ in minutes of arc, where N = the number of sides of a polygon, the number of set-ups where one angle is measured at each set-up, or the number of angles measured about one point. Thus in measuring the angles of a triangle, $E_p = 30''\sqrt{3} = 52$ seconds of arc.

To find the actual angular error of closure in any polygon it should be remembered that the sum of the interior angles is calculated by subtracting 360 degrees from the number of sides multiplied by 180 degrees.

Closed Traverse.- For ordinary transit work on farm surveys the error of closure of a traverse should not be less than 1:1000 if a steel tape is used, or 1:500 if a chain is used. On railway surveys the limit should be 1:1000 to 1:5000 and on City work 1:5000 to 1:10000, the steel tape being used on both of these surveys.

The actual error of closure of a traverse is $E_a = \sqrt{L^2 + D^2}$.

L = algebraic sum of the latitudes, N. latitudes +, S. latitudes -.

D = " " " " departures, E. departures +, W. departure-.

The permissable error of closure = $E_p = 0.0003\, aP\sqrt{N}$ (Tracy)

a = permissable error for one angle.

P = perimeter of the polygon.

N = number of sides of the field.

Baker gives the following formula for permissable linear error of closure: $E_p = P\sqrt{1/d^2 + \frac{a^2}{12000000}}$.

P = length of perimeter.

1/d = Ratio of the chaining error = $\frac{\text{Error in chaining}}{\text{Perimeter}} = \frac{1}{5000}$ for Ry., $\frac{1}{10000}$ for City surveys, etc.

a = angular error of closure of the polygon in minutes of arc.

The table below shows the linear errors due to errors in angle and vice versa. It is convenient for estimating errors due to inaccurate centering of the transit over the tack, inaccurate setting of, or sighting upon, backsights and foresights, etc. An error of one minute of arc gives a ratio of 1:3440 (=sine of one minute), a ratio which is consistent with fair chaining. Since, when reading a transit to minutes of arc, the probable error is 30 seconds, the ratio is 1:6880 which is consistent with very good chaining with a steel tape.

Distance	Angle subtended by 1 foot	Distance subtending 1 minute feet	inches
57.3	1 degree	0.0166	1/5
100	34.4 minutes	0.0291	3/8
500	6.9 "	0.1454	1 3/4
1000	3.4 "	0.2909	3 1/2
1500	2.3 "	0.4363	5 1/4
5000	0.7 "	1.4544	17 7/16
5280	0.65 "	1.5359	18 7/16

An ordinary cross wire in the transit may cover 1/3" in one mile.

STADIA.- In reading distances with the stadia the error in feet should not be greater than $0.05\sqrt{D}$, where D is the total distance in feet.

Where elevations are required to 0.5 foot and lengths of sights are not greater than 300 feet, the distance is read to the nearest foot and the vertical angle to the nearest 15 minutes. The error in vertical angle is seldom greater than 5 minutes and may be as small as 1 minute. Where the slope of the ground is more than 4° or 5° the vertical angle should be read. Best results are obtained in stadia surveys by using sights not over 300 feet long.

CONSISTENT LIMITS OF ACCURACY.- In measuring with a tape to get the area of clearing and assuming that the error of linear measurement is 1:1000, then the error in area would be about 2/1000 times the area. But it is an even chance that the error will be too great as often as too small so that with careful work the error due to inaccuracy of measurement hardly need be considered. The question is rather one concerning the degree of refinement of results and this naturally depends upon the purpose for which they are to be used and the relative effect upon the unit prices involved. For monthly or approximate estimates the work is done hurriedly, consequently with less care and less precise methods than for final estimates. The condition of the work to be measured also prevents close measurements, for example, during the process of clearing there may be several stations where there are brush piles, untrimmed trees, and partially cleared areas; or in grading, the bottom of the cut may be plowed up in furrows. In either case precise measurements with tape or level rod respectively are inconsistent. Since the contractor will finally be paid for all work finished, no injustice is done him if his work is measured up for monthly estimates in a comparatively crude way. It might be observed in this connection that the fact that the engineer can consistently use more exact methods where the work is neatly done should be an incentive to the contractor to burn brush piles, trim trees and clean up as fast as he falls the trees, or slopes the cuts, true up borrow pits, etc., as he proceeds with the excavation, so that he may get the full estimate of work done.

Small jobs or small isolated sections of work should generally be measured more closely in approximate estimates than large ones,

on long continuous sections of work.

In taking field measurements for approximate estimates of earthwork, the rod and tape should be read closely as it takes no longer to read to the nearest 0.1 than to the nearest 0.5, and the more exact information may be useful. It is not necessary in calculations of yardage, though, to carry the results out as far as they are carried for the final estimates.

Rock is given in final estimates only to 0.1 cu. yd. same as earth, since the rod is read the same for both. (nearest 0.1).

The consistent precision is influenced also by methods of handling, whether using hand shovels, scrapers, steam shovels, etc. Hand work is generally regular and completed as it proceeds and, therefore, easily measured with precision, while steam shovel work is rough and irregular and is difficult to measure closely. Time, too, may be a factor. The station and plus of the steam shovel may be observed at 3 P.M. and by 6 P.M. it might be 50' or 100' advanced and several hundred yards removed after the estimate was taken so that an estimate to the nearest 100 cu. yd. might be consistently close as far as the estimate for the month, or its effect upon the contractor, is concerned.

With the above considerations in view and also the allowable errors in the methods as indicated under "Limits of Accuracy", the following limits of consistent results in measuring and calculating are suggested.

TABLE SHOWING RESULTS CONSISTENT WITH MEASUREMENTS

ITEM	UNIT	PRICE	LINEAR MEASUREMENTS APPROX. EST.	LINEAR MEASUREMENTS FINAL EST.	RESULTS ALLOWED APPROX. EST	RESULTS ALLOWED FINAL EST.	Effect upon Price APPROX	Effect upon Price FINAL
CLEARING	ACRE	$35.00	10 ft. to 50 ft.	0.1 ft.	0.1 acre	0.001 acre	$3.50	$.035
"	SQUARE	10.00	10 feet	0.1 "	0.1 square	0.001 square	1.00	.01
GRUBBING	"	15.00	10 "	0.1 "	0.1 "	0.001 "	1.50	.015
"	SQ. ROD	.75	1 foot	0.1 to 0.5 "	1.0 Sq. Rd.	0.1 to 0.01 sq. rd	.75	.075
EARTH EXC.	CU. YD.	.25	0.1 ft. in Ele. 1' to 10' in Dist.	0.1 in Ele. 0.1 in Dist.	10 cu. yds.	0.1 cu. yd.	2.50	.025
ROCK "	" "	.90	0.1 in Ele. 1.0 in Dist.	" "	10 " "	0.1 " "	9.00	.09
WET "	" "	1.50	0.1 in Ele. 1.0 in Dist.	" "	10 " "	0.1 " "	15.00	.15
DRY MASONRY	" "	4.00	1.0 foot	0.1 foot	1 to 5 " "	0.01 " "	4.00	.04
MAS'RY or CONCR'E	" "	8.00	1.0 "	0.05 " or per PLAN	1 to 5 " "	0.01 " "	8.00	.08
BRICK WORK	1000	20.00	1.0 "	per PLAN	100 Brick	1 Brick	2.00	.02
PILING	LIN. FT.	.40	0.1 "	0.1 foot	0.1 foot	0.1 foot	.04	.04
TRESTLE TIM'R	M. M	50.00	0.05 foot or 0.5 inch	0.05 foot or 0.5 inch	0.1 M	0.001 M	5.00	.05
" DECK'G	LIN. FT.	3.00	1.0 foot	0.01 foot	1.0 foot	0.01 foot	3.00	.03
" IRON	LBS.	.04	10 lbs.	1.0 lb.	10 lbs.	1.0 lb.	.40	.04
C.I. PIPE	TONS		lbs. Actual Wt.	lbs. Actual Wt.	lbs. Actual Wt.	lbs. Actual Wt.		
FENCING	MILE	150.00	0.01 mile or 0.5 Station	0.001 mile or 5.0 feet.	0.01 mile	0.001 mile	1.50	.15

Note: All calculations should be carried one decimal place farther than the results to be recorded.

COST OF HAUL

COMPARISON OF DIFFERENT CONVEYANCES

The price is given per cu. yd. measured in excavation; men at 15¢ per hour; horses, 10¢ per hour. The material is "average earth" easily plowed.

RULE	METHOD	LOAD	LENTH OF HAUL in feet Cut to Fill & Cents per CU. YD. 50'	100'	500'	1000'	2000'	5000'	Cost per Yard-Sta.
I	Wheelbarrows	$\frac{1}{15}$ c.y.	20¢	22.5¢	42.5¢	67.5¢	¢	¢	5.00¢
II	1-Horse Carts 1 driver per cart	$\frac{1}{3}$ " "	19	19.2	24.2	30.5	43	77.5	1.25
	" " 1 " to 2 carts	$\frac{1}{3}$ " "	18.9	18.9	22.5	27.0	36	63.0	0.90
	" Large Cart and driver	$\frac{2}{3}$ " "	18.5	18.5	20.8	23.5	29	45.5	0.55
III	Wagons on soft earth roads	$\frac{3}{4}$ " "	18.7	18.7	21.5	26.0	32	53.0	0.70
	" " hard " "	1.3 " "	18.4	18.4	20.0	22.0	26	38.0	0.40
IV	Drag Scrapers	$\frac{1}{9}$ " "	9.0	10.0	26.0	46.0	86		4.00
V	Wheel " No. 1	$\frac{1}{5}$ " "	7.5	8.8	19.8	33.5	61		2.75
VI	" " No. 2	$\frac{1}{4}$ " "	9.2	9.2	18.0	29.0	51		2.20
VII	Wheel Scrapers No. 3 with Snatch Team	0.4 " "	9.5	9.5	14.3	20.3	32	68.0	1.20
VIII	Elevating grader with 3-horse wagons on soft earth roads	$1\frac{1}{4}$ " "	10.5	10.5	10.5	13.0	13.5	28.5	0.50
IX	Cars loaded by hand; 2 cars pulled by one team	5.0 " "	17.0	17.0	17.0	17.0	18.0	21.0	0.10

NOTE: Carts and wheelbarrows are the usual vehicles employed for hauling rock since the excavation is usually worked to a "face". Cars may be used, but wagons seldom.

Table condensed from Gillette.

J.E.S.

CHAPTER XVII

CONVENIENT FORMULAS

Mensuration.

Empirical Formulas for Designing.

Arches.

Retaining Walls.

Weight of Steel Bridges.

Train Resistance.

Elevation of Outer Rail

Consistent Use of Logarithms.

Beam Formulas.

Post and Column Formulas. (For use with piling).

Curve Formulas.

Trigonometric Formulas.

CHAPTER XVIII

USEFUL TABLES

Logarithms of Numbers.

Natural Sines, Cosines and Tangents.

Squares, Cubes, Reciprocals.

Radii of Curves.

Tangent Distances for a One Degree Curve.

Middle Ordinates for Curves.

Middle Ordinates for Bending Rails.

For Finding Degree of Curve.

Latitudes and Departures.

Length of a Degree of Latitude and Longitude.

Areas of Circles.

End Areas for Three Level Section.

Calculating Volumes from End Areas.

Calculating Volumes from Center Heights of Level Sections.

Volume of Triangular Prisms.

Volume of Ballast Per Mile of Track.

Weights and Measures and Conversion of Units.

Weight of One Cubic Foot of Substances.

Weight and Size of Nails and Spikes.

Weight of Track Spikes and Track Bolts.

Weight of Round Iron Rods.

Strength of Materials.

Strength of Timber Beams.

" " Steel.

" " Cement and Concrete.

" " Bridges (Loads).

Proportions of Concrete Mixtures.

Weights and Dimensions of Am. Soc. C. E. Standard Rail Sections.

Temperature Expansion Allowances for Rails.

Elevation of Outer Rail on Curves.

Size and Capacities of Cars (Clearances).

Properties of Frogs and Switches.

Log Scale.